Appendix A

Summary of Results
from
Field Studies

Contents of Appendix A

MOBILE MACHINES

This section of the appendix addresses a broad sample of typical mining machines and considers the visual environment of both the operators and the workers in areas where the machines typically operate. The machines considered ranged from units employed in production areas such as continuous miners, roadheaders, shuttlecars, coal cutters, roofbolters etc. to the more general purpose types of machine used on the mines such as graders, multi-purpose vehicles, load haul dumpers, tractors, personnel carriers, etc.

Each assessment contains:

- Description of the operations observed.
- Key dimensions.
- Sources of illumination.
- Task description.
- Identification and assessment of visual targets.
- Critical visual attention areas.
- Assessment of the visual environment for each visual attention area.
- Significant potential hazards associated with the visual limitations identified

Continuous Miners and Roadheaders

Continuous miners and roadheaders are similar in both design and operation. From an illumination and visibility perspective they are also essentially the same. These two types of machine have, therefore, been considered as a common machine family. Six different machines operating in a range of heading systems and mining activities were examined. The machines were approximately 11m long x 3m wide and ranged in height from 1,0m to 2,0m. In some cases the operators sat on the right side of the machines facing forward approximately 7,5m from the drum. Other machines were remotely controlled. The machines examined were:

1. Standard height continuous miner operating with shuttlecars in a 7,3m (wide) x 3,3m (high) conventional CM section. On-board sources of illumination included:

   Two Maranata triple cluster headlights mounted on the front of the machine.
   Two 600 mm Azolite fluorescent tubes on CM conveyor.
   A red flashing reverse warning light inside cab to left of operator.

2. Low-profile continuous miner operating with shuttlecars in a 6,5 x 1,8m conventional CM section. There were no lights fitted to this machine.

3. Low-profile continuous miner operating with shuttlecars in a 7,0 x 2,0m conventional CM section. On-board sources of illumination included:

   Four 50mm diameter Lohuis Halogen lamps fitted behind the cutter drum. The two inner units were positioned approximately 40cm on either side of the centre-line of the machine. The lights were fitted to the gearbox housing and therefore inclined when the drum was raised. Mounted in this manner, they illuminate the outer edges of the cutting drum.
   One 50 mm diameter x 50w lamp was fitted to the machine behind the driver's seat. The lens had been painted red and the light had been directed to shine upwards to avoid causing glare problems for the shuttlecar drivers This light was switched to automatically illuminate only when reverse mode was selected.

4. Roadheader operating with shuttlecars in a 7,3 x 3,3m stooping section.

5. Standard height **remotely controlled** continuous miner operating with shuttlecars in a 7,3 x 3,3 conventional CM section. On-board sources of illumination included:

   Three 50W CES 'Maxi' headlights mounted in a row across the centre of the machine 1,0m from the rear end of the main chassis of the machine. The lights were inclined upwards to illuminate the upper half of the face.
   A single 'Maxi' light was mounted on the tail of the machine to illuminate the cable entry area.
   Visual aids were provided for the operators in the form of an inclinometer which displayed the angle of the cutting head and a column of three lights which indicated when the cutting drum was at the top and bottom. The top and bottom lights were red and the central light was green.

6. Standard height **remotely controlled** continuous miner operating with a chain haulage system in a conventional CM section.

Assessment details for machines 1 and 5 are given below.

Machine 1 with *on-board operation*

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Cut and load right side of roadway		
Align machine	VT1 Ground/people/obstructions along machine length to right	1 & 2
Tram forward	VT2 Ground/people/obstructions in front of machine up to face	3
Cut and load (following 4 steps repeated 10 to 15 times)		
Raise boom	VT3 Top line of cutting drum/line in strata	
Sump	VT3	
Load to shuttle car	VT4 Shuttle car	4
Cut down	VT5 Lower area of face	3
Reverse out	VT6 Ground/cable/people/obstructions behind machine VT7 Machine Conveyor VT8 People/equipment emerging from entrance of adjacent heading on left side of machine towards the rear	5
Cut and load left side of roadway	VT1-8	
Repeat cycle for right side	VT9 Ground/people/obstructions on left side of machine VT10 Machine/pillar on left side of machine VT11 Vertical line of strata in centre of face from previous cut	5
Move machine to next unit of section	VT6 & 7	5

The visual targets identified above were grouped into the following visual attention areas:

Visual Attention Area: Right-hand side of machines

Visual Targets:	Ground/people/obstructions along machine length to right [VT1]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Primarily caplamps.
Reflectance-	Sidewall dry dull coal. Floor damp but not muddy.
Contrast-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats were white. Other machines were painted white. Supply cables were black.
Visual conditions-	Good during tramming operations when dust levels were low. During cutting and loading visual conditions were poor, especially in the forward facing direction.
Classification-	Detection and course tracking
Operators comments-	No problems

Visual Attention Area: Front of CM

Visual Targets:	Ground/people/obstructions in front of machine up to face [VT2] Top line of cutting drum/line in strata [VT3] Lower area of face (drum - floor interface) [VT5] Vertical line of strata in centre of face from previous cut [VT11]
Operational Blind Spots:	Only right side of cutter drum visible when cutting at floor level. Workers changing picks at left end of cutter drum cannot be seen from operating position.
Major Postural Changes:	None - machine design prevented operator from leaning out of cab.
Visual Environment:	
Visual angle-	Drum roof/floor interface 7,5m from driver.
Illuminance-	Average illumination levels from machine lights 6,0 lux measured 15m in front of machine.
Reflectance-	Sidewall dry dull coal. Floor damp but not muddy.
Contrast-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats were white. Other machines were painted white. Supply cables were black. Cutting drum similar to face/roof because covered with coal dust
Visual conditions-	Good during tramming operations when dust levels were low. High levels of dust and/or water spray obstructed visibility when cutting.
Classification-	Detection and course tracking
Operators comments-	No problems - could feel when cutting head hit floor level.

Visual Attention Area: Rear of CM

Visual Targets:	Shuttle car [VT4] Ground, people and obstructions to rear of machine [VT6] CM conveyor [VT7]
Operational Blind Spots:	Glare from light tubes on conveyor obfuscates view of shuttle car. With the rear conveyor raised there were no blind spots, however, when lowered, only an area from machine centre-line to the near side was visible.
Major Postural Changes:	Drivers had to twist upper body through 180 degrees to look to rear.
Visual Environment:	
Visual angle-	2m wide x 1m high 3,5m from driver People and obstructions at a range of 3,5m (end of m/c) to approx. 5m.
Illuminance-	80 lux measured 1m from the cable entry. 25 lux measured at shuttle car located in loading position.
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats were white. Other machines were painted white. Supply cables were black.
Contrast-	Viewed against - sidewall dry dull coal. Floor damp but not muddy.
Visual conditions-	Good, low dust levels
Classification-	Course tracking
Operators comments-	Lights from rear conveyor make it difficult to see anything behind them.

Visual Attention Area: Left of CM

Visual Targets:	People/equipment emerging from entrance of adjacent heading on left side of machine towards the rear [VT8] Ground/people/obstructions on left side of machine [VT9] Cutting head/pillar on left side of machine [VT10]
Operational Blind Spots:	Totally obstructed by m/c Totally masked by m/c conveyor Cutting head had to be raised to provide visual cue to overcome inability to see left side of m/c.
Major Postural Changes:	Driver has to twist upper body through 180 degrees to see towards the rear.
Visual Environment:	
Illuminance-	None.
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats were white. Other machines were painted white. Supply cables were black.
Contrast-	Viewed against - sidewall dry dull coal. Floor damp but not muddy.
Visual conditions-	Good during tramming operations when dust levels were low. During cutting and loading visual conditions were poor, especially in the forward facing direction.
Classification-	Course tracking
Operators comments-	Operator sometimes requires assistance of a spotter to overcome sight line restrictions to left side of machine.

Deviations from Procedures:

1. Standard Procedures [SPs] stipulate that conveyors should be lowered for reversing. Conveyors were however left in the raised position. It is believed that this was done to avoid collision with shuttle car due to poor visibility.
2. CM drivers switch the machine fans on and off to signal driver of shuttlecar of impending reverse movement.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1 CM strikes cable handler or other members of the workforce when reversing, or traps them against near ribside	Low reflectance and hence poor contrast visibility of workforce due to the use of dark blue overalls. N.B. This limitation is applicable to all the potential hazards relating to striking other members of the workforce.
2 Fire, explosion, burns, etc. from cable damage caused by CM or Shuttle Car	Visibility of power cable poor. (Low reflectance and low contrast visibility of black cable. Cable often obscured by mud). N.B. This limitation is also applicable to potential hazard 7.
3 CM Strikes workers whilst tramming forward or due to inadvertent operation of cutter head during pick changing operations	No pre-start alarm for cutter head operation or pre-tramming alarm fitted.
4 Strikes workers directly behind CM or collides into shuttlecar and pushes it onto workers.	Limited provision of rear lights, reversing lights or alarm fitted to CM. Limited provision of emergency stops fitted to CM particularly in areas of greatest risk. N.B. This limitation is also applicable to potential hazards 5 and 6.
5 Strikes workers or equipment/machines to left-rear of CM	Major blind spot due to machine design. This problem is further exacerbated when lights are fitted to the CM conveyor which create glare and further mask the drivers view of obstructions or pedestrians to the left-rear of the machine.
6 Traps spotters against ribside, especially on the off-side of the machine	Major blind spots due to machine design and limited provision of emergency stops.
7 Workmen/cable handler struck by movement of supply cable.	See hazard 2.

Significant Factors from Other Machines

- The headlight arrangement on Machine 3 provided a useful source of illumination to the sides of the heading in the region of the cutting head (refer to page A2 for layout).
- At the mines where Machines 2 and 3 were examined hard hats in a range of colours were used including dark green and dark blue, which had limited attention-gaining properties.
- Operators of the low-profile machines (Machines 2 and 3) suffered from the effects of glare from the lights of approaching shuttlecars.
- The absence of lights on Machine 2 created difficulties for the operator. When facing forward his only source of illumination was his caplamp and, during cutting operations, he was unable to see the cutting head. When reversing, the machine frequently collided with the shuttlecars. The operators had to signal extensively with their caplamps to the shuttlecar drivers to aid positioning.
- Operators sometimes used spotters to guide them when cutting the off-side. On machines 2 and 3 they were just able to see the heads of the spotters. Operators expressed concern regarding the risk of trapping these men against the ribside.
- On machine 4, the spotters had to climb on top of the machine to a position where the operators could see them. However, no purpose designed access/egress facilities or working platforms were provided.

Machine 5 with *remote control operations*

The remote control feature enables the operator to adopt the most advantageous position from which to see and operate the machine. When cutting and loading, his preferred position was in the region where the cable handler worked i.e. just behind the machine (on the right when looking towards the face). When lining up the machine to cut the left side of the heading the operators took up a similar position on the opposite side of the machine. When backing the machine out to move into a new heading, the operator tended to take up his former position close to the cable handler from where he could see everyone behind the machine. On some occasions however he stood still and allowed the machine to track past him in which case he had only a temporary view of anyone in the path of the machine.

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Cut and load right side of roadway		
Align machine	VT1 Ground/pillar/people/obstructions along machine length to right VT2 Ground/pillar/people/obstructions along machine length to left	2
Tram forward	VT3 Ground/people/obstructions in front of machine up to face	3
Cut and load (following 4 steps repeated 20 to 30 times until full depth of heading had been mined)		
Raise boom	VT4 Top line of cutting drum/line in strata VT5 Indicator lights/inclinometer display on rear of machine/cutter head	
Sump	VT5	
Load to shuttle car	VT6 Machine conveyor VT7 Material load in shuttle car	
Cut down	VT5	
Change shuttlecars	VT8 Replacement shuttlecars	1
Reverse out	VT6 VT9 Ground/cable/people/obstructions behind machine	
Cut and load left side of roadway		
Repeat cycle followed to cut right side	VT1-VT9 VT10 Vertical line of strata in centre of face from previous cut	1, 2, 3
Move machine to next heading	VT6 & 9	2, 3

The visual targets identified above were grouped into the following two visual attention areas:

Visual Attention Area: Forward towards the face of the heading

Visual Targets:	Ground/pillar/people/obstructions along machine length to right [VT1] Ground/pillar/people/obstructions along machine length to left [VT2] Ground/pillar/people/obstructions in front of machine up to face [VT3] Top line of cutting drum/line in strata [VT4] Indicator lights/inclinometer display on rear of machine [VT5] Vertical line of strata in centre of face from previous cut [VT10]
Operational Blind Spots:	When cutting, the whole area of the face including the cutting head was virtually obscured by airborne dust when the cutting head was raised. Vision was also affected by light reflected back from the boom when the boom was raised. The driver was unable to see anyone on the opposite side. The remote control facility does however enable the operator to move round the machine to overcome these visual obstructions.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	It was not possible to measure illumination levels from the machine lights.
Reflectance-	Variable: different coloured overalls worn (blue, green and white). All hard hats white. Machine painted white. Cutting drum similar to face/roof because covered by coal dust.
Contrast-	Viewed against: side walls and roof damp dull coal, floor wet but not muddy.
Visual conditions-	Good during tramming operations but visibility was obstructed by high levels of dust and water sprays during cutting operations. Operator found it almost impossible to control the position of the cutting head by direct vision from his preferred operating position; he relied on the inclinometer and indicator lights to guide the cutting head at the top and bottom of the face.
Classification-	Detection and course tracking
Operators comments-	Expressed a preference for the remote control system over manual control. The advantages of being able to position themselves to see people to the rear and on the traditional blind side of the machine more than compensated for the more limited forward view of the face. See comments in following table for additional risk of being struck by approaching shuttlecars.

Visual Attention Area: Backward i.e. away from the face of the heading

Visual Targets:	Machine conveyor [VT6] Material load in shuttlecar [VT7] Replacement shuttlecars [VT8] Ground/cable/people/obstructions behind machine [VT9]
Operational Blind Spots:	When the driver's attention was focused on other visual targets they would not be able to detect the approach of shuttlecars.
Major Postural Changes:	None.
Visual Environment:	
Illuminance-	It was not possible to measure illumination levels from the machine lights.
Reflectance-	Variable: different coloured overalls worn (blue, green and white). All hard hats white. Machine painted white. Cutting drum similar to face/roof because covered by coal dust.
Contrast-	Viewed against: side walls and roof damp dull coal, floor wet but not muddy.
Visual conditions-	Good during tramming operations but visibility was obstructed by high levels of dust during cutting and loading.
Classification-	Detection and course tracking
Operators comments-	Operator was concerned about being struck by approaching shuttlecars when concentrating on other visual targets especially during cutting and loading operations when visibility was restricted by airborne dust.

Deviations from Procedures:
None identified

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1 Operator and cable handler truck by approaching shuttlecars	Noise from CM mask audible warning from shuttlecars. Airborne dust masks visual presence of shuttlecars
2 Tripping over supply cable	Visibility of power cable poor.
3 CM Striking workers whilst tramming forward, or due to inadvertent operation of cutter head during pick changing operations	No pre-start alarm for cutter head operation or pre-tramming alarm fitted. Operator unable to see workmen in front of machine from preferred operating position, but has the facility to move to a point where he could see them.

Significant Factors from Machine 6

- Machine 6 was not provided with the inclinometer and column of lights to indicate when the cutting head was at the top and bottom. To overcome this limitation the operators routinely adopted a position alongside the machine where there was a risk of trapping themselves against the ribside.
- A taillight had originally been fitted to the conveyor of Machine 6 but this had subsequently been removed because it caused glare problems for the cable handler and the inbye operator of the chain haulage system.

Chain Haulage Systems (CHS)

Chain haulage systems have only recently been introduced to South African coal mining operations. When the project was undertaken only one fully operational system was available for examination. Details and an assessment of this system are given below.

Key Dimensions:

The system is designed to transfer material from the continuous miner to the section belt. The system consists of a series of bridge conveyors interconnected by mobile bridge carriers. The system examined included:

- An inbye mobile bridge carrier (MBC) with a hopper for material collection in front and a rear bridge conveyor;
- Two intermediate MBCs each with a rear bridge conveyor; and
- An outbye MBC with rear bridge conveyor connected to the section belt by a rolling carriage (or dolly).

The MBCs were approximately 10m long, the inbye and intermediate bridges were 12m long and the outbye bridge was 9m long. Each section of the system was connected by sliding pivot joints to its adjoining sections. This enabled the system to operate round turns in the section with drivers out of sight of one another. Communication between the operators was provided by a voice activated communication system.

The power supply cable for the complete system was connected to the rear dolly on the travelling side of the section belt i.e. on the opposite side of the section belt to the CHS.

The MBCs were track driven and a seated operator compartment was provided near the back of each MBC on the right hand side. To improve their lines of sight, operators could raise and lower the complete compartment and swing it out from the mainframe of the machine.

The system was evaluated while working in conjunction with a remotely controlled continuous miner. The roadway/heading section was 6m x 2,2m.

Sources of Illumination:

The three MBCs were virtually identical in terms of their lighting provision which included the following:
A single 50W Hytronic headlight provided centrally on top of the machine some 2m behind the water sprays.
Two small sidelights mounted low down on the front of the machine

The CM was fitted with the following:
A pair of white reversing lights, which illuminate automatically when reverse travel, is selected.
A light unit fitted to the tail of the machine had been removed due to repeated damage through impact with the inbye MBC.

The section belt roadway was provided with an ad hoc arrangement of 1,5 m flameproof fluorescent lights that were constantly being re-located as the section advanced.

Task Descriptions

The responsibility of the leading driver was to maintain the hopper of the inbye MBC under the discharge conveyor of the CM. This was achieved by tracking the unit backwards and forwards in unison with the CM. The responsibility of the following drivers was to track their MBCs (making turns where necessary) to maintain station on the bridge conveyor in front of them. The trailing operator had the added responsibility of checking the operation of the rolling carriage on the section conveyor. During material transfer, forward and reverse tracking did not normally exceed 20m, however, when advancing the system to start a new heading a 100m reverse and forward movement would not be uncommon. Water sprays were provided on the front of each MBC to control dust levels. The visual targets required by the operators when loading out and during forward and reverse movements are indicated below. Except where stated the visual targets listed applied to all operators.

Visual Targets	**Principle Operations**			**Hazard No**
	Loading Out	**Moving Forward**	**Moving Backward**	
VT1 CM operator, cable handler and supply cable for CM		✓		1, 2
VT2 Discharge conveyor from CM (driver of inbye MBC)	✓			
VT3 Outbye ends of bridge conveyors(in front of drivers of intermediate and outbye MBCs)	✓	✓	✓	
VT4 Reversing lights on CM and MBCs			✓	9
VT5 Water sprays	✓			
VT6 Ground/ribsides/people/obstructions along machine length to the right		✓	✓	1
VT7 Ventilation ducting on right side of roadway		✓	✓	3
VT8 Ground/ribsides/people/obstructions along machine length to the left		✓	✓	1
VT9 Section conveyor to the right		✓	✓	
VT10 Roof	✓	✓	✓	3
VT11 Bridge conveyors behind			✓	8,9
VT12 Ground/ribsides/people/obstructions to the rear			✓	9
VT13 Rolling carriage of outbye bridge conveyor (driver of outbye MBC)	✓	✓	✓	8

The visual targets identified above were grouped into the following visual attention areas:

Visual Attention Area: Facing forwards

Visual Targets:	CM operator, cable handler and supply cable [VT1] Discharge conveyor from CM [VT2] Outbye ends of bridge conveyors [VT3] Reversing lights on CM and MBCs [VT4] Water sprays [VT5] Ground/ribsides/people/obstructions along machine length to the right [VT6] Roof [VT10]
Operational Blind Spots:	There were no blind spots in terms of the operator's vision being cut-off, however, lighting levels on the visual targets was limited - see below.

Major Postural Changes:	None.
Visual Environment:	
Illuminance-	Measurements taken directly in front of the hopper of the inbye MBC 1,0m off the ground were: zero left front corner, 5 lux dead centre, and zero right front corner. The maximum level recorded in front of the hopper was 10 lux. Output from the two small sidelights mounted low down on the front of the machine was negligible. Measurements of only 5 lux were obtained at a point 1,0m directly in front of the units. The units were recessed within the framework of the machine and were coated in dirt. Removal of the dirt improved the measured output by 100% i.e. to 10 lux. Very little effective light fell on the visual targets defined. Maximum output from the headlights of the two outbye MBCs was 20 lux measured at the delivery point of the bridge conveyor. These lighting levels did however not cover the area since they were obstructed by the spray system
Reflectance-	Variable. Workmen seen wearing various coloured overalls i.e. white, blue, green, etc. All hard hats white. CM painted white but covered in coal dust. Supply cables black.
Contrast-	Viewed against - Sidewalls dry dull coal. Floor damp but not muddy with heavy accumulations of coal spillage.
Visual conditions-	Due to the combination of high dust levels and poor standard of headlighting, operators of the inbye MBC had problems seeing the CM operator and cable handler. Also, the inbye operators view of VT2 and the outbye operators view of VT3 were extremely limited because the output from the single headlights on top of the units were obstructed by high levels of dust during loading.
Classification-	Detection and course tracking.
Operators comments-	Inbye operator considered that forward visibility was appalling due to combination of a totally inadequate CM scrubber system, and lighting provision on his own machine and the removal of the light unit from the CM.

Visual Attention Area: Facing to the right

Visual Targets:	Ground/ribsides/people/obstructions along machine length to the right [VT6] Ventilation ducting on right side of roadway [VT7] Section conveyor [VT9]
Operational Blind Spots:	None
Major Postural Changes:	Some difficulties experienced by operators looking towards the rear over their right shoulders.
Visual Environment:	
Illuminance-	Caplamp illumination only. Headlights on the outbye machines did not penetrate far enough to illuminate the right side of the roadway adjacent to the machine in front.
Reflectance-	Variable. Workmen seen wearing various coloured overalls i.e. white, blue, green etc. All hard hats white. CM painted white but covered in coal dust. Supply cables and ventilation ducting black.
Contrast-	Viewed against - Sidewalls dry dull coal. Floor damp but not muddy with heavy accumulations of coal spillage.
Visual conditions-	Poor. When loading the air was laden with dust and there was no effective lighting down the side of the machine. It was reported that the capacities of the bridge conveyors and MBC were low in relation to the CM with the result that considerable spillage occurred at the various discharge points. This resulted in large accumulations of loose material building up in the walking side of the heading which was essentially in darkness.
Classification-	Detection and course tracking.

Operators comments-	The ventilation ducting in the side of the roadway was vulnerable to damage from the machine when turning corners and it also represented a potential tripping hazard to pedestrians.

Visual Attention Area: Facing to the left

Visual Targets:	Ground/ribsides/people/obstructions along machine length to the left [VT8]
Operational Blind Spots:	Operators would be unable to see anyone crouching down anywhere along the length of the MBC even with their seats fully raised.
Major Postural Changes:	None, with the seat swung out the operators had little difficulty looking towards the off-side.
Visual Environment:	
Illuminance-	None, The headlights on the outbye machines did not penetrate far enough to illuminate the left side of the roadway adjacent to the machine in front.
Reflectance-	Variable. Workmen seen wearing various coloured overalls i.e. white, blue, green etc. All hard hats white. CM painted white but covered in coal dust. Supply cables and ventilation ducting black.
Contrast-	Viewed against - Sidewalls dry dull coal. Floor damp but not muddy with heavy accumulations of coal spillage.
Visual conditions-	Poor. When loading the air was laden with dust and there was no effective lighting down the side of the machine.
Classification-	Detection and course tracking.
Operators comments-	

Visual Attention Area: Facing backwards

Visual Targets:	Bridge conveyors behind [VT11] Ground/ribsides/people/obstructions to the rear [VT12] Rolling carriage of outbye conveyor [VT13]
Operational Blind Spots:	None
Major Postural Changes:	Some difficulties experienced by operators looking towards the rear over their left shoulders.
Visual Environment:	
Illuminance-	There were no lights fitted to the rear of the MBCs Headlights from following MBCs had very little benefit for the drivers of the leading machines when looking to the rear. Output levels were low and when the system was being operated round a series of turns, the lights were concealed.
Reflectance-	Variable. Workmen seen wearing various coloured overalls i.e. white, blue, green etc. All hard hats white. CM painted white but covered in coal dust. Supply cables and ventilation ducting black.
Contrast-	Viewed against - Sidewalls dry dull coal. Floor damp but not muddy with heavy accumulations of coal spillage.
Visual conditions-	Poor, through a combination of the conditions described for the other visual areas.
Classification-	Detection and course tracking.
Operators comments-	The facility to swing out the seat reduces postural difficulties (i.e. improves sight lines to the visual targets) but poor standard of lighting limits visibility.

Deviations from Procedures:

1. The scrubber system on the CM was reportedly not working correctly.
2. Rear light on the tail of the CM had been removed to prevent damage.
3. Lights on these machines did not comply with the regulatory 10 lux at 20m.

General Comment on Sight Line Restrictions

The chain haulage system examined was designed primarily for use in low-seam applications. Research directed towards summarising the application of ergonomics for improving safety, identified the operator's field of vision as a problem in the design of low-seam equipment. While the system examined satisfies many of the ergonomic recommendations relevant to the design of low-height cabs, from a sight lines perspective, it is inappropriate for use in thick seam headings. The visual restrictions placed on the operators are unnecessary.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Operators, cable handlers and other workmen trapped between leading MBC and CM	High visibility reflective clothing not worn. NB this limitation also applies to Hazard 8. Restricted forward vision caused by dust and spray from the CM blown into the face of the inbye operator. Also, inadequate spread of light from headlights and output impaired by dusty air and heavy accumulations of dust. NB these limitations also apply to Hazard 2.
2. Injuries caused by driving over and damaging the supply cable to the CM	See above
3. Drivers injured by objects entering the workspace.	Inadequate levels of illumination along the sides of the system
4. Slipping, tripping and falling crossing over the machine.	Failure to provide purpose designed crossing points featuring adequate levels of illumination and freedom from 'hidden' tripping hazards.
5. Trapped between the cable handler and ribside in the section belt travelway.	Inadequate provision of mine lighting in section belt travelway. NB this limitation also applies to Hazard 6.
6. Tripping and falling over spillage and cables lying on the floor in the section belt travelway.	Inadequate handling and stowage of cables etc. (Also see hazard 5) Housekeeping substandard
8. Workmen trapped between the CHS and ribsides/obstacles, particularly on the off-side and to the rear.	Obstructed lines of sight to the off-side and rear. Lack of adequate illumination to the rear of the units. NB these limitations also apply to Hazard 1.
9. Reversing into people and obstacles.	Lack of provision of effective visual/audible warnings of reverse movement.

Shuttlecars

A range of different shuttlecars is used on the mines ranging from low-profile to high profile units. The systems of mining in which they are employed also differ. The machines examined were approximately 8m long x 3m wide and ranged in height from 1,0m to 2,5m. In all cases the operators sat approximately 6m from the inbye loading end in dual seating arrangements which allowed them to face either direction of travel without having to adopt awkward driving postures. Normally in any given section two versions of the machine are used, one with the cab on the left side and the other with the cab on the right. For safety and logistical reasons the machines travel different routes which join only at the heading and feeder breaker. The purpose of dedicating left and right cab machines to specific routes is to provide the drivers with an optimum view of the feeder breaker when they approach from the different roadways. The following four shuttlecars were examined working in conduction with continuous miners, roadheaders and loaders in CM sections, stooping sections and drill and blast sections.

1. Medium height shuttlecar operating in a 7,3m x 3,3m CM section. Sources of illumination included:

   Twin 50mm diameter 50W headlights mounted at both ends 1,0m above ground level 300mm in from the corners, all of which illuminate when machine is switched on regardless of travel direction.
   Two 0,6 m Azolite Fluorescent light tubes on CM conveyor.
   Two 2,4 m fluorescent tubes in Azolite flameproof fittings suspended 0,5m from roof 1m apart almost directly above the tipping point

2. Medium height shuttlecar operating in a 6m x 3,3m drill and fire section in conjunction with a loader. On-board sources of illumination included:

   Single 50mm diameter 50 W headlight mounted at the inbye end of the vehicle.
   Twin 50mm diameter 50 W headlights mounted at the outbye end of the vehicle
   The above headlights were switched automatically to illuminate the direction of travel selected.
   A 12v 50W taillight fitted to the loader was defective.
   Three 1,5 m fluorescent tubes in Azolite flameproof fittings suspended 0,5m from roof at the tipping point

3. Low-profile shuttlecar operating in a 6,5m x 1,8m CM section. On-board sources of illumination included:

   Twin 50mm diameter 50W headlights mounted 1,0m and 0,5m above ground level, 300mm in from the corners at the outbye and inbye ends respectively.
   No taillights were provided on the CM during loading operations.
   The tip was very well lit by several 2,4m fluorescent tubes suspended 0,8m from the roof.

4. High-profile shuttlecar operating in a 7,3m x 4m stooping section in conjunction with a roadheader. On-board sources of illumination included:
   Twin 50mm diameter 50W headlights mounted 1,0m above ground level at the outbye and inbye ends respectively.
   The above headlights were switched manually by the operator to illuminate the direction of travel selected.
   No details were obtained of the lighting provided by the CM or at the tip.

Assessment details for machine 1. are given below.

Hierarchical Task Description (Machine 1)

Task Elements	Visual Targets	Hazard No.
Loading		
Approach CM	VT1 Cable handler working behind CM to the right VT2 Cable to CM VT3 Other workmen and obstacles in roadway between shuttlecar and CM	1 & 2
Manoeuvre machine under discharge conveyor	VT4 Conveyor structure, top of material in shuttlecar and rear of CM	2
Forward/reverse movement to even loading	VT4 VT5 Workmen and equipment behind shuttlecar i.e. in path of loading end of shuttlecar VT6 CM driver communications (by 'light' signals)	3
Travel to feeder breaker		
Change seating position		
Set off	VT7 Workmen and obstacles in path of discharge end of shuttlecar	5
Negotiate nearside turns (i.e. left turns when cab is on the left and right turns when cab is on the right).	VT8 Near corner of roadway being turned into VT9 Far corner of roadway being turned into VT10 Workmen and equipment in entrance of turning	5
Negotiate offside turns (i.e. left turns when cab is on the right and right turns when the cab is on the left)	VT11 Near corner of roadway being turned into VT12 Far corner of roadway being turned into VT10	5
Discharging	VT13 Workmen and other shuttlecars/machines in area	
Approach feeder breaker	VT14 Leading tyres of shuttlecar and baseframe of feeder breaker - to avoid collision	
Manoeuvre machine against feeder breaker		6
Discharge load at controlled rate	VT15 Material on feeder breaker	
Travel to loading point		
Change seating position		
Set off	VT16 Workmen and obstacles in path of loading end of shuttlecar	5
Negotiate near side turns (i.e. left turns when cab is on the left and right turns when cab is on the right).	VT17 Near corner of roadway being turned into VT18 Far corner of roadway being turned into VT10	5
Negotiate offside turns (i.e. left turns when cab is on the right and right turns when the cab is on the left)	VT20 Near corner of roadway being turned into VT21 Far corner of roadway being turned into VT10	5

The visual targets identified above were grouped into the following visual attention areas:

Visual Attention Area: Facing forwards (towards the CM) during loading

Visual Targets:	Cable handler working behind CM to the right [VT1] Cable to CM [VT2] Workmen and obstacles in roadway between shuttlecar and CM [VT3] Conveyor structure, top of material in shuttlecar and rear of CM [VT4] Workmen and equipment on path of loading end of shuttlecar [VT5] CM driver - to communicate/reverse warning light in CM cab [VT6]
Operational Blind Spots:	On shuttlecars where the cab is on the left when the driver faces the CM, the conveyor obscures a substantial area. The following would be virtually obscured: • The CM cable and cable handler • Any other workmen and obstacles that were not directly in front of the driver. • The CM driver and reverse warning light in the CM cab. When the cab is on the right, visibility is better but any other workmen and obstacles that were not directly in front of the driver would still be obscured.
Major Postural Changes:	None: driver has dual seats and is prevented from leaning out of cab.
Visual Environment:	
Illuminance-	25 lux from CM lights measured at point of interface with shuttle car in loading position. Average illumination across roadway from shuttlecar headlights = 5 lux at 20m. Caplamp illumination from cable handler
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white. CM painted white. Supply cables black.
Contrast-	Viewed against - Sidewalls dry dull coal. Floor damp but not muddy.
Visual conditions-	Obstructed by high levels of dust during loading.
Classification-	Detection and course tracking.
Operators comments-	Reported damage to cable every month Shuttlecar lighting could be improved

Visual Attention Area: Facing backwards in opposite direction to the CM during loading

Visual Targets:	Workmen and equipment in front of discharge end of shuttlecar [VT7]
Operational Blind Spots:	Blind spot in front of shuttle car on opposite to driver masks view of other workmen, shuttlecars and machines in close proximity.
Major Postural Changes:	Driver has to twist upper part of body through 180 degrees to see.
Visual Environment:	
Illuminance-	Average illumination across roadway from headlights = 12,5 lux at 20m. Some additional illumination from other shuttlecars queuing in turn-off roadways.
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white.
Contrast-	Viewed against - Sidewalls dry dull coal. Floor damp but not muddy.
Visual conditions-	Obstructed by high levels of dust during loading.
Classification-	Detection and course tracking.
Operators comments-	Shuttlecar lighting could be improved

Visual Attention Area: Facing forwards i.e. in direction of travel towards the discharge end of the shuttlecar when travelling to the feeder breaker

Visual Targets:	Workmen and obstacles in path of discharge end of shuttlecar [VT7] Near and far corners of nearside turns [VT8] & [VT9] Near and far corners of offside turns [VT11] & [VT12] Workmen and equipment in entrance of turning [VT10] Leading tyres of shuttlecars and baseframe of feeder breaker to avoid collision [VT14]
Operational Blind Spots:	Area in front of shuttle car on opposite to driver obscured by conveyor. Near corner of and entrance into offside turns completely obscured by conveyor.
Major Postural Changes:	None: driver has dual seats and is prevented from leaning out of cab.
Visual Environment:	
Illuminance-	Average illumination across roadway from headlights = 12,5 lux at 20m.
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white. Other shuttlecars white. Scoop (grader) orange.
Contrast-	Viewed against - Sidewalls dry dull coal in heading area; poor standard of stone dusting elsewhere. Floor damp but not muddy.
Visual conditions-	Good, low dust levels during tramming.
Classification-	Detection and course tracking
Operators comments-	Reported ‘bumps’ with other shuttlecars every month. Some drivers take it on themselves to stone dust the corners of the more difficult turns Their biggest concern is running someone over during this aspect of their work. Shuttlecar lighting could be improved

Visual Attention Area: Facing forwards when discharging at the feeder breaker

Visual Targets:	Workmen and other shuttlecars in area [VT13] Leading tyres of shuttlecar and baseframe of feeder breaker - to avoid collision [VT14] Material on feeder breaker [VT15]
Operational Blind Spots:	Blind spot in front of shuttle car on opposite to driver masks view of other shuttlecars in position at feeder breaker. Unable to see base frame of feeder breaker
Major Postural Changes:	None: driver has dual seats and is prevented from leaning out of cab.
Visual Environment:	
Illuminance-	Average illumination across roadway from headlights = 12,5 lux at 20m. Illumination level on top of feeder breaker from mine lighting = 25 lux.
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white. Other shuttlecars white. Feeder breaker structure white.
Contrast-	Viewed against - Sidewalls have poor standard of stone dusting. Floor damp but not muddy.
Visual conditions-	High levels of dust when discharging does not influence driver performance.
Classification-	Detection and course tracking.
Operators comments-	Shuttlecar lighting could be improved

Visual Attention Area: Facing forwards i.e. in direction of travel towards the loading end of the shuttlecar when travelling towards CM

Visual Targets:	Workmen and obstacles in path of shuttlecar [VT16] Near and far corners of nearside turns [VT17] & [VT18] Near and far corners of offside turns [VT20] & [VT21] Workmen and equipment in entrance of turnings [VT10]
Operational Blind Spots:	Substantial area in front of shuttle car obscured by conveyor. Driver, located 6m from front of machine has very restricted field of vision and can see only directly ahead. Near corner of and entrance into offside turns completely obscured by conveyor.
Major Postural Changes:	None: driver has dual seats and is prevented from leaning out of cab.
Visual Environment:	
Illuminance-	Average illumination across roadway from headlights = 5 lux at 20m.
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white. Other shuttlecars white. Scoop (grader) orange.
Contrast-	Viewed against - Sidewalls dry dull coal in heading area; poor standard of stone dusting elsewhere. Floor damp but not muddy.
Visual conditions-	Good, low dust levels during tramming.
Classification-	Detection and course tracking.
Operators comments-	Reported ‘bumps’ with other shuttlecars every month. Some drivers take it on themselves to stone dust the corners of the more difficult turns to improve visibility Their biggest concern is running someone over during this aspect of their work. Shuttlecar lighting could be improved

Overall Comment from Operators Regarding Illumination

Between the two cones of light produced by the twin set of lights at each end of the vehicles was an area of dark shadow, which extended 5m to 10m from the vehicle. It was very difficult to detect people and obstacles in this area.

Deviations from Procedures:

1. Parking brakes were not applied when the shuttlecars were being loaded to minimise the extent of collision damage when the CM backs out. Unbarred, the shuttlecars 'bounce' off the CM and anyone standing behind the shuttlecar was at risk from being struck.
2. Instructions state that anyone who has to stand behind the CM must take up a position on the right (next to cable handler). When shuttlecars with left hand cabs are on station they felt safer standing on the left and therefore violated this instruction.
3. Average level of illumination from the machine lights at the loading end was 5 lux at 20m. This is less than the specified 10 lux given in the current industry standards.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1 Shuttlecar strikes or traps people against the CM when closing up with CM	Shuttlecars with cab on left have very restricted visibility to the right so that CM cable handler and workmen on the right are at particular risk. Shuttlecars with cab on the right have very restricted visibility to the left so that workmen on the left are at particular risk. Low reflectance and hence poor contrast/visibility of workforce due to use of dark blue overalls
2 Fire, explosion, burns, etc. from CM cable damage caused by shuttlecar with cab on left side closing up with CM. [Reportedly cable damage is caused at least once a month]	Visibility of power cable is poor. Greatest risk comes from shuttlecars with cab on left where sight lines to the right are particularly restricted.
3 Workmen struck by unexpected reverse movement of shuttlecar.	Drivers of shuttlecars with cab on left are unable to see reverse warning light on CM. CM collides with shuttle car which 'bounces' into workmen. Lines of sight to workmen behind machine obstructed on all vehicles. Low reflectance and hence poor contrast/visibility of workforce due to use of dark blue overalls.
4 Collision between shuttlecars where main travel roads converge at working headings. [Collisions reportedly occurred at least once a month]	Lack of effective traffic controls where one-way travel roads converge. Machine lighting fails to provide adequate warning to drivers of other vehicles. Lack of clearly audible travel alarms on shuttlecars

5 Strikes workmen, scoop and grading machines and the corners of turns on the off-side of the shuttlecar when travelling in either direction between CM and feeder breaker. [A workman was run-over and received a fractured pelvis one month before the study]	No restrictions on workmen using haulage routes. Onus is placed on workmen looking out for themselves if they are not to be run-over. Lines of sight to off-side of all machines is obstructed. Low reflectance and hence poor contrast, visibility of workforce due to use of dark blue overalls. Stone dusting does not keep pace with advancement of headings [Some drivers take it on themselves to stone dust the corners of the more difficult turns] to improve visibility.
6 Collision between shuttlecars queuing at feeder breaker and with feeder breaker. Pedestrians also trapped at this point. [During the study a near-miss between two shuttlecars and one shuttle car colliding with the feeder breaker was observed].	While dedicating left and right cabs to specific routes provides optimum view of discharge operations, it restricts view of other shuttlecars. Lack of effective traffic controls where the three travel roads converge. Machine lighting fails to provide adequate warning to drivers of other vehicles. Limited sight lines and lack of positional aids.

Significant Factors From Other Shuttlecars

Machine 2. medium-height unit

- Illumination levels were as follows.

  Single headlight (inbye end):
  With the foot removed from the accelerator pedal, lighting levels across the roadway barely reached 1 lux at a distance of 20m.
  With the accelerator fully depressed lighting levels across the roadway varied between 1 and 5 lux.
  Up to a distance of 5m no light was transmitted to the right side of the roadway; the light beam was obstructed by the conveyor/front of machine.

  Twin headlights (outbye end).
  Average illumination across roadway was 5 lux at 20m.

- The feeder breaker was too high for the shuttlecar to discharge into without negotiating a ramp. When inclined on the ramp, the front end of the machine obstructed the driver's forward view. To see adequately they had to leave their seat and operate the vehicle from a standing position. There was therefore a risk that they could fall from the vehicle during this manoeuvre.

Machine 3. low-profile unit

- Illumination levels with clean lenses were as follows.

Twin headlights at inbye end
14 lux measured 5m ahead of and along the centre-line of the vehicle

Twin headlights at outbye end
4 lux measured 16m ahead of the vehicle at points across the roadway.

- The roadways in which this machine was examined were covered in 200mm to 300mm of soft mud. This affected the operators visual environment in the following respects:

  Headlights were always plastered in mud and dust. Before cleaning light output was not measurable. After cleaning average levels of illumination 5m from the light source at the inbye end of the vehicle was 14 lux.

Mud thrown up by the wheels of the shuttle car significantly reduced the reflectivity of stone dust.

Electrical supply cables in the section were concealed in the mud.

- Neither the shuttlecars (nor their drivers) were provided with any audible warning device.
- One of the headlight mountings at the outbye end of the unit was loose with the result that the light was inclined vertically upwards and was of little value.
- Sight lines towards the off-side of the machine were completely obscured from the drivers with the result that the vehicles were regularly in collision with the corners of pillars when turning. There was therefore also an increased risk of trapping people against the ribside.
- To avoid striking their heads against unseen objects in the roof and to direct their caplamps along the roadway ahead drivers tended to lean out of the cab when travelling.
- Stone dusting activities failed to keep up with face advancement.
- The muddy conditions outlined above combined with the absence of any taillights on the CM increased the risk of trapping workmen against the CM.
- Due to poor levels of illumination combined with the sight line restrictions operators miss-judged the clearance between the conveyor and the roof with the result that collisions were commonplace.

Machine 4. high-profile unit

It was not possible to take lighting measurements for this machine. There were no other significant factors identified.

Loading Machines

Loading machines were examined in drill and blast production sections. Only one type of machine was identified and this was a pedestrian operated, track driven, gathering-arm loader that was used in conjunction with shuttlecars. Details and an assessment of the system are given below.

Key Dimensions:

All roadways, intersections and faces in the section were 6,0m wide x 3,5m high and the pillar width was 20m.
The loader was an electrically powered track driven machine approximately 8m long x 2m wide x 1,2m high. An outboard control/operating station was provided midway along the right side of the machine i.e. approximately 4m from the gathering arms at the front. The operator had to stand or walk in this position at the side of the machine to control any tramming and loading operations.
The discharge conveyor overhanging the rear of the machine was pivot mounted and had to be swung over when loading the shuttlecar and when tramming round corners.
The loading team consisted of three men: the machine operator, the cable handler and a general assistant whose main duty involved watering down the product with a hose pipe.

Sources of Illumination:

Machine was fitted with Hytronic 12v 50W headlights (white) at both front and rear ends, all of which illuminated when machine was switched on regardless of travel direction selected. A pair of these units facing forwards were mounted immediately in front of the control station on the right side of the machine. A single rearward facing unit was mounted immediately behind the control station. This unit had, however, been covered over and was valueless (see deviations below).
Additional illumination from other machines when tramming.
Caplamp illumination from driver and cable handler and occasionally from other workmen in the section.

Task Description

Machine Operations - The following table considers visual targets of the machine operator only.

Task Elements	**Visual Targets of Machine Operator**	Hazard No
Tram machine to new face		
Lower boom and raise spade	VT1 Spade VT2 Boom VT3 Controls	
Tram backwards out of face	VT4 Cable handler, other workmen and obstacles behind machine at ground and roof level VT5 Slip/trip hazards in path of operator VT6 Supply cable	1, 2, 3, 4, 5, 8

Reverse turn machine at intersection Swing boom over Slew machine	VT3, VT2, VT4, VT5, VT6 VT7 Far side walls and corner of roadway and any people or obstacles along far side of machine VT8 Near side walls and corner of roadway and any people or obstacles along near side of machine VT9 Far wall of roadway being reversed into.	1, 2, 3, 4, 5,8
Tram forward (straighten boom and machine)	VT2, VT3, VT4, VT5, VT7, VT8 VT10 Workmen and obstacles in front of machine	1, 2, 3, 4, 5,8
Negotiate left and right turns	VT2, VT3, VT4, VT5, VT7, VT8, VT10	1, 2, 3, 4, 5,8
Stop loader at right hand side of pillar	VT5, VT8, VT10 VT11 Loose coal/spade	1, 2, 3, 4, 5
Loading operations		
Lower spade	VT1,	
Tram forward and load to solid (includes raising and positioning boom over shuttlecar and examining for misfires).	VT2, VT4, VT5, VT7, VT8, VT11 VT12 Shuttlecar including driver. VT13 Attendant with water hose.	3, 4, 6, 5, 7, 8
Tram to subsequent working places in heading and repeat previous task element	VT3, VT4, VT5, VT6, VT7, VT8, VT9 VT11, VT12, VT13	1, 2, 3, 4, 6, 7, 8

The visual targets identified above were grouped into the following five visual attention areas**:**

Visual Attention Area for Machine Operator during Tramming and Loading Operations
Front of machine

Visual Targets:	Spade [VT1] Workmen and obstacles in front of machine [VT10] Loose coal/spade [VT11]
Operational Blind Spots:	Occasionally, when loading, dust obliterates operator's view of gathering arms with result that large lumps can be loaded into shuttlecar.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Measurements taken 0,5m off the ground directly in front of machine i.e. 4m from light unit were: 160 lux at front near side corner of machine along centre-line of light 180 lux along centre-line of machine 60 lux at front far side corner of machine With machine parked in centre of roadway, measurements taken 0,5m off the ground 20m in front of machine were: 20 lux on near side of roadway i.e. driver's side 20 lux in centre of roadway 10 lux on left side of roadway
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. All other vehicles were painted white. Gathering arms and spade were shiny metallic colour. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate and dust levels were low after face had been prepared. Illumination levels towards off side front corner were poor.
Classification-	Identification/course tracking
Operators comments-	The floor area where the operator works is not illuminated. Spillage/lumps of coal in this area poses a trip hazard

Near side of machine (at operator station)

Visual Targets:	Controls [VT3] Slip/trip hazards in path of operator [VT5] Near side walls and corner of roadway and any people or obstacles along near side of machine [VT8] Attendant with water hose [VT13]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen wore white hard hats, dark blue overalls and reflective yellow waistcoats. All other vehicles were painted white. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate and dust levels were low after face had been prepared.
Classification-	Identification/course tracking
Operators comments-	As for front of machine

Off side of machine

Visual Targets:	Far side walls and corner of roadway and any people or obstacles along far side of machine [VT7] Attendant with water hose [VT13]
Operational Blind Spots:	When boom was raised during loading operations anyone standing on the off side rear quarter of the machine would not be visible to the operator. Similarly, large obstructions would not be visible.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen wore white hard hats, dark blue overalls and reflective yellow waistcoats. All other vehicles were painted white. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate and dust levels were low after face had been prepared.
Classification-	Identification/course tracking
Operators comments-	None

Rear of machine

Visual Targets:	Boom [VT2] Cable handler, other workmen and obstacles behind machine at ground and roof level [VT4] Supply cables [VT6] Far walls of roadway being reversed into [VT9] Shuttlecar including driver [VT12]
Operational Blind Spots:	When loading, shuttlecar and driver was partially obscured by boom in raised position. When boom was lowered when tramming, anyone crouching behind the machine would be partially obscured. Similarly, small obstructions, supply cables and hazards at ground level would be obscured.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	With rear facing headlight covered over, there was essentially no illumination to the rear except that provided by caplamps from the operator and cable handler. With the covering removed, illumination measurements taken 0,5m off the ground 20m behind the machine were: 8 lux on near side of roadway 8 lux in centre of roadway 5 lux on off side of roadway Measurements taken 0,5m off the ground directly behind the machine i.e. 4m from the light were: 100 lux near side rear corner along centre-line of light 5 lux at centre-line of machine 5 lux at off side rear corner of machine
Reflectance-	All workmen wore white hard hats, dark blue overalls and reflective yellow waistcoats. All other vehicles were painted white. Chain conveyor was shiny metallic colour. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Air speed was moderate and dust levels were low after face had been prepared. Illumination was poor however

	because rear facing light caused glare problems and was covered over. When covered, machine operator and cable handler had to rely on caplamps
Classification-	Identification/course tracking
Operators comments-	None

Cable Handling

The cable handler had a limited number of primary visual targets that required his attention during almost all of the task elements described above for tramming and loading operations. These visual targets are tabulated below.

Visual Attention Area for Cable Handler during Tramming and Loading Operations

Visual Targets:	Supply cable VT_1 Back of machine VT_2 Slip/trip hazards on floor VT_3 Machine operator to communicate VT_4 Other machines and obstacles behind VT_5
Operational Blind Spots:	None, however, glare from rear facing light before it was covered (see deviation below) obliterated cable handlers view towards rear end of machine.
Major Postural Changes:	Frequent bending down to handle supply cable
Visual Environment:	
Illuminance-	See previous table for illumination levels from single rear facing headlight. With headlight covered only light was from caplamps of cable handler and machine operator.
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. This and other vehicles were painted white. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor, while air speed was moderate and dust levels were generally low, illumination was poor. Rear facing light caused glare problems and left half roadway in dark shadow. When light was covered, cable handler had to rely on his caplamp.
Classification-	Identification/course tracking.
Operators comments-	None

Deviations from Procedures:

1 Machine operator did not use whistle when cornering, approaching people in roadway, and as means of communication with shuttlecar driver.
2 Operator stood on machine to direct his caplamp to front offside corner while loading.
3. Rear reversing light was covered to reduce glare problems
4. Output from rear facing headlight did not comply with statutory 10 lux at 20m.
5. Attendant with hose pipe watering down coal was seen working on off side of machine instead of next to operator.
6. When tramming, cable handler was seen closer than minimum 3m distance from machine (he apparently adopted this position to compensate for poor illumination levels.)

7. Tracking over objects on floor.
8. Methanometer was not used at roof level when preparing face for loading.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Fire, explosion, burns, etc. caused by running over cables	Low reflectance and hence poor contrast of power cable with ground. Restricted sight lines and dark shadow behind machine.
2. Reverses into cable handler and other plant/machines	Lack of illumination behind machine predisposes the tendency for cable handler to work too close to machine Machine not fitted with any form of warning to denote intended reverse movement Restricted sight lines and dark shadow behind machine.
3. Operators injured by tracking machine over their own feet	Operators attention diverted by other visual targets
4. Operator and other workmen crushed through inadvertent slewing of machine	No apparent restrictions on presence and movement of workmen in working area when loading No 'operator in position' feature fitted to automatically stop machine if driver stumbles
5. Driver injured by objects turned up by tracks	Lack of illumination to off side front corner of machine Lack of control over presence of hazards in roadway
6. Driver injured falling off machine	Failure of machine lights to illuminate important visual targets predisposed operator to stand on machine and use caplamp to identify visual targets
7. Collision with shuttlecar	Poor vision and lighting to rear of machine
8. Drives into people in roadway	See control limitations for Hazard 2 Warning whistles not used.

Face Drilling Machines

Face drilling machines were examined in drill and blast production sections. Only one type of machine was identified and this was a wheel driven machine operated from a seated forward facing operating position. Details and an assessment of the machine is given below.

Key Dimensions:

All roadways, intersections and faces in the section were 6,0m wide x 3,5m high and pillar width was 20m.
The machine was an electrically powered four wheeled unit. The driver sat facing forwards under a canopy on the right side of the machine at a point midway between the front and rear wheels. Cable and hose connection to the machine were at the rear corner on the drivers side. The drilling boom extended forward of the front wheels by 5m. In addition to the electrical supply cable, water for drilling was supplied to the machine by a hose

Sources of Illumination:

The machine was fitted with three Hytronic 12v 50W S11 headlights (white), mounted on top of the drivers canopy facing forwards and a single light unit of the same type located on the rear of the machine. All the lights illuminated when the machine was switched on regardless of travel direction selected.

The three forward facing units were equally spaced across the canopy which extended half way across the machine. The right hand light was inclined downwards and to the left by 10 degrees and the other two were directed straight ahead.

The rear light was mounted 0,5m off the ground behind the driver adjacent to the cable entry, and pointed directly ahead.

Hierarchical Task Description

Machine operations - The following table considers visual targets of the machine operator only

Tram machine to new face		Hazard No.
Reverse from previously bolted heading	VT1 Machine controls VT2 Ground/cable/cable handler and other people, machines and obstructions behind machine VT3 Supply cable	1 & 2
Turn machine in roadway	VT1, VT2, VT3 VT4 Off-side walls and corner of roadway and any people or obstacles along the off-side of the machine VT5 Near-side walls and corner of roadway and any people or obstacles along near side of machine VT6 Far wall of roadway being reversed into i.e. behind machine	1, 2, & 3
Tram forward	VT2 VT7 Workmen and obstacles in front of machine	3
Negotiate left and right turns and enter new heading	VT1, VT2, VT4, VT5, VT7 VT8 Roof over working area.	3
Drill new heading (following steps repeated between 15 and 18 times before moving to new heading)		
Manoeuvre machine in position for first hole	VT1, VT2, VT3, VT4, VT5, VT7.	1, 2 & 3
Align drill	VT1 VT9 Chalk marks on face	
Drill	VT1, VT9	
Retract dill	VT1, VT9	

The visual targets identified above were grouped into the following five visual attention areas**:**

Visual Attention Area for Machine Operator during Tramming and Drilling Operations

Facing towards the front of the machine

Visual Targets:	Machine controls [VT1] Workmen and obstacles in front of machine [VT7] Roof over working area [VT8] Chalk marks on face [VT9]
Operational Blind Spots:	When tramming, much of the roadway towards the off-side was obscured from the driver by the bolting rig.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Light output 20m directly in front of the operators cab 1,0m off the ground when the boom was set horizontally and pointed straight ahead for tramming measured 10 lux. At the opposite side of the roadway corresponding measurements were 5 lux in places where the light beams were unobstructed, however, in places the boom obstructed the beams and zero measurements were recorded.
Reflectance-	All workmen wore white hard hats, various coloured overalls (dark blue, green, white, etc.) often with no reflective strops. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were originally orange but had become black with ingrained coal dust.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good for tramming, air speed was moderate and dust levels were low. Wet drilling was employed which virtually eliminated dust problems.
Classification-	Identification/course tracking
Operators comments-	Major concerns were: Operators greatest concern was hitting people with the end of the protruding drilling boom when travelling. People in the roadway are dazzled by the three lights fitted to the machine cab and are unable to detect the boom until it is literally only 0,5m away from them.

Near-side of machine

Visual Targets:	Near-side walls and corners of roadway and any people or obstacles along the near-side of the machine [VT5]
Operational Blind Spots:	None
Major Postural Changes:	Operators have to turn through 180 degrees to see the near-side of the roadway to their rear.
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen wore white hard hats, various coloured overalls (dark blue, green, white, etc.) often with no reflective strips. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were originally orange but had become black with ingrained coal dust.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good for tramming, air speed was moderate and dust levels were low. Wet drilling was employed which virtually eliminated dust problems.
Classification-	Identification/course tracking

Operators comments-	None

Off-side of machine

Visual Targets:	Off-side walls and corners of roadway and any people or obstacles along the off-side of the machine [VT4]
Operational Blind Spots:	Most of the off-side of the roadway below the operators eye height was out of view.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen wore white hard hats, various coloured overalls (dark blue, green, white, etc.) often with no reflective strips. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were originally orange but had become black with ingrained coal dust.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good for tramming, air speed was moderate and dust levels were low. Wet drilling was employed which virtually eliminated dust problems.
Classification-	Identification/course tracking
Operators comments-	Considerable concern about turning the machine onto anyone on the off-side although workmen have been warned that it is potentially unsafe to work on that side.

Rear of machine

Visual Targets:	Ground/cable/cable handler and other people, machines and obstructions behind machine [VT2] Supply cable [VT3] Far wall of roadway being reversed into i.e. behind machine [VT6]
Operational Blind Spots:	An area of ground extending approx. 6m from the machine could not be seen from the driving position. It was not possible to see the cable handler when he was bending down in this area.
Major Postural Changes:	Need to rotate body through 180 degrees.
Visual Environment:	
Illuminance-	Lighting measurements taken 1m off the ground 5m from the machine when the machine was located in the centre of the roadway were: 20 lux directly in front of the light 15 lux at the near side of the roadway 5 lux on the opposite side of the roadway Corresponding measurements taken at 20m were: 5 lux, 3 lux and zero. Surplus supply cable was wound round bollards on the rear of the machine. This cable interfered with light output with the result that very little light was transmitted to the off-side of the roadway.
Reflectance-	All workmen wore white hard hats, various coloured overalls (dark blue, green, white, etc.) often with no reflective strips. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were originally orange but had become black with ingrained coal dust.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. While air speed was moderate and dust levels were low, illumination was poor. Off-side half of roadway was in darkness. Rear facing light caused glare problems on the near-side. If the light was covered everything behind the machine was left in dark shadow and the operator and cable handler would have to rely on their caplamps.
Classification-	Identification/course tracking

Operators comments-	Operator claimed that an improved arrangement of illumination should be provided but could not elaborate on specifics.

Cable Handling

The cable handler had a limited number of primary visual targets that required his attention during almost all of the task elements described above for tramming and loading operations. These visual targets are tabulated below.

Visual Attention Area for Cable Handler

Visual Targets:	Supply cable [VT_1] Back of machine [VT_2] Slip/trip hazards on floor [VT_3] Machine operator - to communicate [VT_4] Other machines and obstacles behind [VT_5] Roof and previously set bolts directly above in new heading [VT6]
Operational Blind Spots:	None, however, glare from rear facing light obliterated cable handler's view towards rear end of machine.
Major Postural Changes:	Frequent bending down to handle supply cable
Visual Environment:	
Illuminance-	See previous table for illumination levels from rear facing headlight.
Reflectance-	All workmen wore white hard hats, various coloured overalls (dark blue, green, white, etc.) often with no reflective strips All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were originally orange but had become black with ingrained coal dust.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. While air speed was moderate and dust levels were generally low, illumination was poor. Rear facing light caused glare problems and the obstructing supply cables combined with the absence of a rear off-side, light left half the roadway in dark shadow.
Classification-	Identification course tracking
Operators comments-	Cable handler claimed that he faced unnecessary risks due to the conditions outlined above.

Deviations from Procedures:

1. Output from both front and rear headlights did not comply with 10 lux at 20m.
2. Machine operator did not use whistle when cornering, approaching people in roadway and as a means of communication with other machine operators.

Note the standard versions of this machine used at the colliery were fitted with only two forward facing headlights. These machines were criticised by the operators on the grounds of inadequate forward illumination. The above 'modified' machine was considered to be the ideal in this respect and the three-light arrangement is to be replicated on the other machines.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Fire, explosion and burns etc. caused by running over supply cables	Low reflectance and hence poor contrast of power cable with ground Restricted sight lines and areas of dark shadow behind machine Postural difficulties when drivers attempt to look to rear
2. Reverses into cable handler and other plant/machines	Lack of illumination behind machine predisposes the tendency for cable handler to work too close to machine Machine not fitted with any form of warning to denote reverse movement Restricted sight lines and dark shadow behind machine Postural difficulties when drivers attempt to look to rear Stone dusting not applied in working areas
3. Drives into people in roadway	Restricted sight lines and levels of illumination to front off-side of machine Workmen in roadway affected by glare from machine headlights and unable to see tip of protruding drill boom. Warning whistles not used Limitations in the use of high visibility clothing No audible travel alarm system
4. Cable handlers trip in roadway over obstacles, cable and lengths of hose.	Restricted sight lines and dark shadow behind machine.

NOTES

The mine has fitted water tanks to roofbolting machines to eliminate the hazard associated with trailing hoses.

The lights fitted to this machine, although considered by the mine to be ideal for drilling, created additional hazards during tramming operations.

Roofbolting Machines

Several different types of roofbolting machines operate in a range of different heading systems and mining activities. The machines can be track driven or wheel propelled, provided with seated or standing operating positions and can be used in CM sections, stooping sections, drill and fire sections and developments for the installation of mechanical or resin bonded bolts. The three machines examined were:

1. A track driven unit approximately 3,0m long x 1,8m wide provided with an **out-board** control/operating station mid-way along the left side of the machine. The machine was examined while installing resin bonded bolts in a 6,0m x 3,5m drill and fire production section. On-board sources of illumination included:

   Two Hytronic 12v 50W headlights (white), one at each end of the machine, all of which illuminated when the machine was switched on regardless of travel direction selected.
   The forward facing unit was mounted on top of, in virtually the dead centre of the machine facing forward so that the bolting rig largely obstructed the light.
   The rear facing light was mounted on the extremity of the machine at the left corner but had been covered with a cardboard box “because it dazzled workmen in the section”.

2. A wheel propelled unit approximately 3,0m long x 1,8m wide provided with a forward facing seated operating position at the rear left corner. The machine was examined while installing mechanical bolts in a 7,3m x 3,3m CM section. On-board sources of illumination included:

   Two lights on the machine directed at the roof. One light was mounted near the rear of the machine adjacent to the operators cab and the other was mounted virtually in the centre of the machine. The rear light was originally provided with an adjustable mounting to enable the operator to adjust the beam direction to different circumstances but at the time observations were made the light was clamped rigidly in a fixed position. (The original adjustable mounting was defective and would not support the light properly).

3. A track driven version of the above machine. The machine was examined while installing resin bonded bolts in a stooping section. On-board sources of illumination included:

   Two Hytronic 12v 50W headlights (white), one at each end of the machine, all of which illuminated when the machine was switched on regardless of travel direction selected. The lights were mounted on the front and rear right corners of the machine. The rear light was masked to reduce glare problems.
   A 0,9 m flameproof fluorescent light tube mounted on the drill rig raise/lower boom.
   A spot light located on an adjustable mounting next to the operator.

A complete operational cycle was observed for each of the above machines, which included movement of the roofbolter from a previously bolted heading to a new unsupported heading and the bolting operations undertaken therein. In all cases, workmen involved in the operation included the machine operator and an assistant who fed the bolts to the machine rig and handled the supply cable during tramming.

Assessment details for machines 1 and 2 are given below.

<u>Machine 1.</u> -track driven with out-board control station

Hierarchical Task Description

Machine operations - The following table considers visual targets of the machine operator only

Tram machine to new face		Hazard No.
Reverse from previously bolted heading	VT1 Machine controls VT2 Ground/cable/cable handler and other people, machines and obstructions behind machine VT3 Slip/trip hazards in path of operator VT4 Supply cable	1, 2, 3, 5
Turn machine in roadway	VT1, VT2, VT3, VT4 VT5 Far (right) side walls and corner of roadway and any people or obstacles along far side of machine VT6 Near (left) side walls and corner of roadway and any people or obstacles along near side of machine VT7 Far wall of roadway being reversed into i.e. behind machine	3, 4
Tram forward	VT1, VT2, VT3, VT5, VT6 VT8 Workmen and obstacles in front of machine	1, 3, 5, 6
Negotiate left and right turns and enter new heading	VT1, VT2, VT3, VT5, VT6, VT8	3, 4, 5, 6
Bolt new heading (following steps repeated up to 10 times before moving to new heading)		
Manoeuvre machine in position for first bolt	VT1, VT2, VT3, VT5, VT6, VT8, VT10 VT14 Assistant working on the ground	3, 4
Assistant (stood on top of drill rig) loads drill into rig	VT9 Assistant on top of machine	7
Align drill and cram to roof	VT1, VT9 VT10 Roof over working area VT11 Drill/marking in roof	7, 8
Drill	VT1, VT9, VT10, VT11	7, 8
Assistant feeds resin ampoules into hole	VT9, VT10	7
Assistant replaces drill with bolt	VT9, VT10	7
Insert and set bolt	VT1, VT9, VT10 VT12 Bolt/drill hole in roof VT13 Bolt plate	7, 8

The visual targets identified above were grouped into the following six visual attention areas**:**

Visual Attention Areas for Machine Operator during Tramming and Bolting Operations

Front of machine

Visual Targets:	Machine controls [VT1] Workmen and obstacles in front of machine [VT8] Assistant on top of machine [VT9] Roof over working area [VT10] Drill/marking in roof [VT11] Bolt/drill hole in roof [VT12] Bolt plate [VT13] Assistant working on the ground [VT14]
Operational Blind Spots:	When tramming, much of the roadway was obscured from the driver by the bolting rig.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Measurements taken 0,5m off the ground in front of the machine 5,0m from the light units were: 5 lux at the left, centre and right side of the roadway Measurements taken 1,0m off the ground in front of the machine 5,0m from the light units varied between 10 lux and 100 lux depending on whether the light was obstructed by the drill rig.
Reflectance-	All workmen wore white hard hats, dark blue overalls, yellow reflective waist coats. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good for tramming, air speed was moderate, and dust levels were low. During bolting operations dust restricted view of most visual targets.
Classification-	Identification/course tracking
Operators comments-	Major concerns were: Operator's greatest concern was accidentally slewing the machine and crushing himself against the side of the roadway. Possible causes of this were slipping and falling, attention directed elsewhere and distractions. Other concerns were: • Running into someone in front of machine as a result of being unable to see them • Running over obstacles on the floor which could be turned up by the tracks and injure someone • Dazzled by lights from other machines which shone all the time regardless of whether these machines were reversing or whether rear light illumination was required at the time. • Failing to see something critical during bolting operations.

Near (left) side of machine

Visual Targets:	Machine controls [VT1] Slip/trip/fall hazards in path of operator [VT3] Near (left) side walls and corner of roadway and any people or obstacles along nearside of machine [VT6] Assistant working on the ground [VT14]
Operational Blind Spots:	No definable blind spots, but operators attention is divided and it was difficult for him to pay adequate consideration towards identifying any potential hazards on the floor
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen wore white hard hats, dark blue overalls, yellow reflective waist coats. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate, and dust levels were low.
Classification-	Identification/course tracking
Operators comments-	Concerned about not seeing obstacles on the floor and obstacles turned up by machine tracks

Off (right) side of machine

Visual Targets:	Far (right) side walls and corner of roadway and any people or obstacles along far side of machine [VT5] Assistant working on the ground [VT14]
Operational Blind Spots:	With the driver stooping to operate the controls most of the right side of the machine essentially represents a blind area. (See driver's comments below regarding his concern over hitting his assistant.)
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen wore white hard hats, dark blue overalls, yellow reflective waist coats. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate, and dust levels were low.
Classification-	Identification/course tracking
Operators comments-	Considerable concern about slewing machine onto assistant working on right (blind) side of machine

Rear of machine

Visual Targets:	Ground/cable/cable handler and other people, machines and obstructions behind machine [VT2] Supply cable [VT4] Far wall of roadway being reversed into i.e. behind machine [VT7]
Operational Blind Spots:	When stooped to operate the controls a substantial area behind the machine was obscured from the driver. This would include the cable handler if he was also stooping, and the supply cable.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	With the rear light covered there was effectively no illumination to the rear except that provided by caplamps from the operator and cable handler. With the covering removed, illumination measurements taken 1,0m off the ground 20m behind the machine were: 10 lux on the off side of the roadway 8 lux in the centre of the roadway 5 lux on the near side of the roadway Measurements taken 1,0m off the ground 5m behind the machine were: 15 lux at the off and near sides of the roadway 20 lux in the centre of the roadway
Reflectance-	All workmen wore white hard hats, dark blue overalls, yellow reflective waist coats. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. While air speed was moderate and dust levels were low, illumination was poor. Rear facing light caused glare problems. When light was covered everything behind the machine was left in dark shadow and the operator and cable handler had to rely on their caplamps.
Classification-	Identification/course tracking
Operators comments-	Operator claimed that a totally improved system of illumination should be provided but could not specify.

Cable Handling/Assisting Bolting

The cable handler/bolting assistant had a limited number of primary visual targets that required his attention during almost all of the task elements described above for tramming and loading operations. These visual targets are tabulated below.

Visual Targets
Cable handling (assistant working at ground level behind machine):
VT_1 Supply cable
VT_2 Back of machine
VT_3 Slip/trip hazards on floor
VT_4 Machine operator to communicate
VT_5 Other machines and obstacles behind

Assisting with bolting operations (assistant on top of machine for duration of bolting:
VT6 Roof and previously set bolts directly above
VT7 Machine operator to communicate
VT8 Drive head
VT9 drill and bolt shanks
VT10 Resin ampoules
VT11 Resin seepage from bolt holes
VT12 Top surface of machine
VT13 Convenient foot and handholds used to climb on and off machine

Visual Attention Area for Cable Handler/Bolting Assistant

Tramming operations (i.e. cable handling assistant working at ground level behind machine)

Visual Targets:	Supply cable [VT1] Back of machine [VT2] Slip/trip hazards on floor [VT3] Machine operator - to communicate [VT4] Other machines and obstacles behind [VT5]
Operational Blind Spots:	None, however, glare from rear facing light before it was covered caused glare and obliterated cable handlers view towards rear end of machine (see 'illuminance' comments below).
Major Postural Changes:	Frequent bending down to handle supply cable
Visual Environment:	
Illuminance-	See previous table for illumination levels from rear facing headlight. With headlight covered, only light was from caplamps of cable handler and machine operator.
Reflectance-	All workmen wore white hard hats, dark blue overalls, yellow reflective waist coats. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets were black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. While air speed was moderate and dust levels were generally low, illumination was poor. Rear facing light caused glare problems and left half the roadway in dark shadow. When light was covered cable handler had to rely on caplamp.
Classification-	Identification course tracking
Operators comments-	Cable handler claimed that he faced unnecessary risks due to conditions outlined above.

Bolting operations (i.e. assistant on top of machine for duration of bolting)

Visual Targets:	Roof and previously set bolts above [VT6] Machine operator to communicate [VT7] Drive head [VT8] Drill and bolt shanks [VT9] Resin ampoules [VT10] Resin seepage/spray from bolts [VT11] Top surface of machine [VT12] Convenient foot and handholds used to climb on and off machine [VT13]
Operational Blind Spots:	None, although assistant claimed that his eye protectors become so dirty by the end of a bolting cycle that he was essentially working blind. Also, having to look directly above caused neck ache and as consequence he was unable to do this on a continuous basis Foot holes on the sides of the machine were obscured
Major Postural Changes:	See note above regarding neck ache
Visual Environment:	
Illuminance-	Forward facing machine light provided little useful illumination to the area of roof being bolted. At the point of the drill as it entered the roof light measurements of only 25 lux were recorded.
Reflectance-	All workmen in white hard hats, dark blue overalls, yellow reflective waist coats. All other vehicles were painted white. Chalk marks on the roof were white although other visual targets (bolt accessories, etc.) were dark grey or black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. Considerable dust was created when drilling which, coupled with the restricted vision through dirty eye protection, tended to partially obscure most of the visual targets at roof level.
Classification-	Identification/course tracking
Operators comments-	Need something to reduce dust generation, an extra light pointing upwards to aid bolting operations, and formal steps and handholds for climbing onto the machine.

Deviations from Procedures:

1. Output from both front and rear headlights did not comply with 10 lux at 20m.
2. Assistant roofbolter rode on top of machine when machine was repositioned to new bolting position.
3. Cable handler and workmen were seen operating closer than minimum 3m distance from machine (cable handler apparently adopted this position when tramming to compensate for poor illumination levels.
4. Machine operator did not use whistle when cornering, approaching people in roadway and as a means of communication with other machine operators.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Fire, explosion and burns, etc. caused by running over supply cables	Low reflectance and hence poor contrast of power cable with ground Restricted sight lines and areas of dark shadow both in front and behind machine
2. Reverses into cable handler and other plant	Lack of illumination behind machine predisposes the tendency for cable handler to work too close to machine Machine not fitted with any form of warning to denote reverse movement Restricted sight lines and dark shadow behind machine
3. Operators injured by tracking machine over their own feet	Operators attention diverted by other visual tasks
4. Operator and other workmen crushed through inadvertent slewing of machine	No 'operator in position feature' fitted to automatically stop machine if driver stumbles Failure by workmen to maintain the regulation 3m from the machine
5. Driver and other people injured by obstacles turned up by tracks	Restricted sight lines and illumination limit view of obstacles in path of machine Lack of control over presence of objects in roadway
6. Drives into people in roadway	See control limitations for hazard 2 Warning whistles not used
7. Assistant falls off machine	Limitations in access provision in terms of design, visibility and provision of illumination to foot and handholds Similar limitations in design of machine as a working platform
8. Assistant hit by falling roof material, resin from bolt holes, bent drills, etc.	Poor visibility of roof under operational conditions due to lighting limitations and high dust levels generated

Machine 2. - wheel propelled with on-board control station

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Move machine to new heading		
Reverse from previously bolted heading	VT1 Ground/cable/cable handler and other people/shuttlecars/obstructions behind machine. VT2 Ground/people/obstructions close to the machine to the right. VT3 Ground/people/obstructions close to the machine to the left.	1, 2 & 3
Turn machine in roadway	VT1, VT2, VT3.	1, 2 & 3
Tram forward and enter new heading	VT4 Workmen/obstacles/supply cables/other machines (CM, shuttlecars etc.) in front of machine.	1, 2 & 3
Bolt new heading (following 4 steps repeated up to 50 times before moving to new heading).		
Manoeuvre machine in position for first bolt	VT2, VT3, VT4 VT5 Roof of heading	1 & 3
Assistant loads bolt into drill rig	VT6 Ruts and obstacles on the ground in the vicinity of the machine VT7 Drivehead and retaining mechanism on drill rig VT8 Roof over working area.	4, 5 & 6
Align drill rig and cram to roof	VT5, VT7	
Assistant moves to back of machine	VT6, VT8	
Drill and set bolt	VT9 Tip of drill and bolt VT5	

The visual targets identified above were grouped into the following three visual attention areas**:**

Visual Attention Areas for Machine Operator/Driver
Right, left, front and rear of machine (when tramming)

Visual Targets:	Ground/cable/cable handler and other people/shuttlecars/obstructions behind machine [VT1] Obstacles on the ground/people/obstructions close to machine to the right [VT2] Obstacles on the ground/people/obstructions close to machine to the left [VT3] Workmen/obstacles/supply cables/other machines (CM, shuttlecars etc.) in front of machine [VT4]
Operational Blind Spots:	View to rear of machine partially obstructed by towing hitch davit mounted centrally on back of machine. Forward view severely obstructed by combination of drill rig and glare from machine lights.
Major Postural Changes:	Driver has to twist through 180 degrees to see to the rear.
Visual Environment:	
Visual angle	People and obstructions at a range of 1,0m (end of m/c) to approx. 5m.
Illuminance-	Primarily caplamp illumination from machine driver/operator and assistant (machine lights provide minimal assistance when tramming).
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white. Other machines painted white. Supply cables black.

Contrast-	Viewed against – Sidewall dry dull coal. Floor damp but not muddy.
Visual conditions-	Poor, resulting from lack of tramming lights and extreme postures that have to be adopted driver/operator frequently 'bumps' into obstructions when manoeuvring.
Classification-	Detection and course tracking
Operators comments-	Driver/operator expressed concern about being struck by shuttlecars when backing out of heading and striking assistant when manoeuvring in position for bolting operation.

Roof (when bolting)

Visual Targets:	Roof of heading [VT5] Tip of drill and bolt [VT9]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Visual angle-	Approximately 3 square metres of roof approx. 3 metres from the operating position
Illuminance-	10 lux measured at point where drill enters roof
Reflectance-	Low - Roof strata/drill steel/bolts.
Contrast-	Low - Drill steel/bolts/hanging material viewed against roof strata. Viewed against - Sidewall dry dull coal.
Visual conditions-	Poor. High levels of dust when drilling. When ground is not level rear light does not effectively illuminate visual attention area.
Classification-	Detection and course tracking
Operators comments-	None

Visual Attention Areas for Assistant

Visual Targets:	Ruts and obstacles on the ground in the vicinity of the machine [VT6] Drivehead and retaining mechanism on drill rig [VT7] Roof over working area [VT8]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Visual angle-	Approximately 3 square metres of roof
Illuminance-	10 lux measured at point where drill enters roof plus caplamp. 5 lux at point where bolts are located to drivehead plus caplamp. On average, 5 lux from machine lights plus caplamp.
Reflectance-	Variable: Roof strata/drill steel/bolts; machine elements white painted; ground damp coal.
Contrast-	Viewed against roof strata, ribsides dull coal, floor damp.
Visual conditions-	Poor: absence of general lighting. Machine lighting of only moderate benefit.
Classification-	Detection/identification
Operators comments-	Loose material left in headings by continuous miner create significant tripping hazard.

Deviations from Procedures:

1. Machine was not fitted with front and rear headlights for tramming purposes.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1 Machine strikes cable handler or other members of the workforce, or traps them against the roadway walls when tramming.	No headlights, rear lights, reversing lights or tramming alarm fitted. Restricted sight lines, particularly to the front and rear. Low reflectance and hence poor contrast visibility of workforce due to use of dark blue overalls. Lack of effective traffic control system
2 Fire, explosion, burns, etc. from damage to supply cable to machine and cables to other machines (CM, Shuttlecars etc.)	Visibility of power cables is poor.
3 Back injuries caused by frequent major postural changes	Uni-directional seat arrangement and visual obstruction caused by towing davit.
4 Assistant hit by falling roof material	Poor visibility of roof under certain conditions.
5 Assistant traps/knocks hand feeding bolt to bolting rig.	Visibility of potential trapping points is poor.
6 Assistant trips and falls while moving round the machine	Visibility of obstacles and cables in roadway is poor.

Significant factors from Machine 3. - track driven version of Machine 2.

Illumination levels were as follows:

- The flameproof fluorescent light mounted on the drill rig raise/lower boom provided good all round levels of illumination. Light measurements of 100 lux were recorded at the point where the drill enters the roof.
- The rear light was masked to reduce glare problems experienced by the assistant when cable handling and by other workmen in the section. With the masking removed output levels of 40 lux were measured 5m from, and directly in line with, the light. The cable hanger, however, limited the spread of light to the opposite side of the roadway. Output from this unit was negligible when the masking was in place.
- The single headlight was mounted behind a range of hydraulic hoses which restricted roadway illumination. Maximum illumination levels in line with the light on the right side of the roadway was 3 lux at 10m. Output was negligible on the left side.

Load-Haul-Dump machines (LHDs)

Most LHDs are fitted with two to three cubic metre capacity buckets and are used to transport supplies as well as coal to wide-spread locations throughout the mines. A characteristic of these vehicles is that the driver cabs are located centrally on one side with the drivers seated in a sideways position. In most cases the driving position is provided on the left side of the vehicle when looking towards the bucket but a minority of vehicles have right-sided cabs.

A range of small battery powered scoops, used primarily for clearing up spillage from shuttlecars and levelling the ground churned up by the shuttle car wheels, can also be considered within this family of machines. They have side seating arrangements and are fitted with buckets on the front end (similar, but on a smaller scale to the buckets fitted to LHDs).

The following five units were examined.

1. A large vehicle approximately 7,5m long x 1,8m wide x 1,8m high with the driving position on the left. The vehicle was observed transporting supplies between a shaft station and an underground workshop complex over a distance of 0,5 km in 6,0m x 2,5m section roadways. Sources of illumination comprised:

   Two 12v 50W Hytronic headlights mounted at each end of the machine. At the front (bucket) end, a light unit was mounted on the top of each mud-guard. At the rear, the lights were mounted in front of the radiator, approximately 1,0m off the ground, one close to each corner of the machine.

   The roadway was illuminated by twin 75W, 1,8m fluorescent light units mounted laterally across the roof every 25m. No light units were however provided within 10m of any junction

2. A large vehicle, similar to Vehicle 1, transporting supplies in an underground workshop complex in which roadway sections varied. Sources of illumination comprised:

   This vehicle was fitted with an identical arrangement of lights as Vehicle 1.

   The roadways were extremely well illuminated by various arrangements of fluorescent lights.

3. A medium height vehicle approximately 6,0m long x 1,8m wide x 1,3m high with the driving position on the right. The vehicle was observed transporting supplies inbye to a production section along a 7,0m x 1,8m section roadway. Sources of illumination comprised:

   Two 12v 50W Hytronic headlights mounted at the front (bucket) end of the vehicle on top of each mud-guard. At the rear, a single headlight of the same type was mounted in front of the radiator, approximately 0,75m off the ground, close to the right corner of the vehicle

   The roadway was illuminated by twin 75W, 2,4m fluorescent light units mounted laterally across the roof every 25 m.

4. A medium height vehicle approximately 6,0m long x 1,8m wide x 1,5m high with the driver on the left. The vehicle was observed travelling outbye from a production section along a 7,0m x 2,0m section roadway. Sources of illumination comprised:

   Two 50mm diameter 50W headlights mounted at each end of the vehicle. At the front (bucket) end a light unit was mounted on the top of each mud-guard. At the rear the lights were mounted one on either side of and at the end of the engine compartment, approximately 1,0m off the ground. A red reflector was mounted on the radiator grille.

   The roadway was illuminated by twin 75W, 2,4m fluorescent light units mounted laterally across the roof every 25 m.

5. A small pivot steered purpose designed battery powered scoop with the driver on the right. The vehicle was observed clearing up spillage and levelling the ground in a 7,3m x 3,3m section roadway in a production section. Sources of illumination comprised:

   Two 50mm diameter 50W headlights mounted at each end of the vehicle. The lights were mounted at each corner on top of the vehicle approximately 0,6m off the ground and were directed downwards to illuminate a line across the roadway approximately 5m ahead of the scoop. All the lights illuminate when the machine is switched on regardless of travel direction selected.

Assessment details for Vehicles 1 and 5 are given below.

Assessment of Vehicle 1
Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Travel to shaft station (bucket loaded with empty oil drums)		
Raise and tilt bucket to travelling position	VT1 Workmen and obstacles directly in front of and at the sides of the bucket VT2 Top of bucket and roof above the bucket	1, 8
Set off bucket leading	VT1, VT2 VT3 Workmen and obstacles alongside the pivot point on the off side of the vehicle VT4 Workmen and obstacles alongside the pivot point on the near side of the vehicle	1, 2, 3, 4, 5
Negotiate left turns	VT1, VT2 VT5 Near corner of roadway being turned into VT6 Far corner of roadway being turned into VT7 Near side of vehicle VT8 Leading off side corner of bucket VT9 Workmen and equipment in entrance to turning (left)	1, 2, 3, 4, 5, 7
Negotiate right turns	VT1, VT2 VT10 Near corner of roadway being turned into VT11 Far corner of roadway being turned into VT12 Top edge of vehicle running down off side VT13 Leading near side corner of bucket VT14 Workmen and equipment in entrance to turning (right)	1, 2, 3, 4, 5, 7
Travel along straight stretch of roadway	VT1-4 VT15 Workmen and obstacles (ground/sides/roof) far enough in front of the vehicle for them to be detected and identified to enable the vehicle to be stopped before collision.	1, 2, 3, 4, 5
Cross over junction	VT9 & 14	1, 2, 5, 7
Approach shaft station and stop	VT1, 2, 3, 4, 15	1, 2, 3, 5, 6
Unloading		
Tilt and lower bucket to ground	VT1	1, 6
Supplies crew lift empty drums from bucket and store at side of shaft station		1, 4, 6
Travel back to workshop	When travelling back to the workshops the vehicle was driven in reverse. The task hierarchy and visual targets that were required were essentially the same except that they were encountered in the reverse order. When travelling in reverse visibility was slightly better because there was no bucket to obstruct the driver's sight lines and output from the vehicle headlights.	1, 2, 3, 4, 5, 8

The visual targets identified above were grouped into the following visual attention areas:

Facing forwards (towards the bucket)

Visual Targets:	Workmen and obstacles directly in front of and at the sides of the bucket [VT1] Top of bucket and roof above the bucket [VT2] Workmen and obstacles (ground/sides/roof) far enough in front of the vehicle for them to be detected and identified to enable the vehicle to be stopped before collision [VT15]
Operational Blind Spots:	A substantial area in front of the vehicle, particularly towards the off side, was obscured by the bucket and items on top of the vehicle. It was not possible to see the ground in front of the bucket up to a distance of 60m. The driver conceded that at 60m it was not possible to reliably detect and identify people and the nature of obstacles and hazards in the path of the vehicle. Furthermore, it was not possible to see even the hard hat of a 1,8 m tall workman standing erect directly in front of the bucket between the centre line of the vehicle and the right front corner. When travelling in reverse i.e. bucket trailing, the driver, when looking towards the rear of the vehicle, could see only the top of the hard hat of a 1,8 m tall workman extending above the engine compartment.
Major Postural Changes:	Driver has to rotate upper part of his body through 180 degrees to see ahead of the vehicle. Canopy and side of vehicle did not prevent him from leaning out of cab.
Visual Environment:	
Illuminance-	With the bucket raised in the travelling position output from the headlights was not measurable at 20m. With the bucket lowered average illumination across the roadway at 20m with engine running at above idle speed was 20 lux (similar output levels were recorded for the headlights mounted on the rear of the vehicle). With engine running at **idle speed** light output was **not measurable** at 20m. Roadway lights – measurements taken 1m off the ground Directly beneath lights: 240 lux in centre of road Between lights: 50 lux in centre of road
Reflectance-	All workmen wore white hard hats, dark blue overalls and reflective yellow waistcoats. Most other vehicles were painted white but some tractors were blue.
Contrast-	Viewed against: Main roadway ribsides were coated with stone dust with poor reflective properties, walls were dry compacted coal dust.
Visual conditions-	Poor, Machine lights extinguish at low engine revs Roadway lights are covered in dust and only emit a fraction of their potential output. Some critical areas, such as junctions, not illuminated
Classification-	Identification and course tracking
Operators comments-	Driver expressed concern about: Hitting people who may be crouched at the side of the vehicle Collisions with other vehicles parked at the side of the road and at junctions, especially on the off side Masking of headlights by the bucket when driving through areas where mine illumination levels was low Running over debris in the roadway.

To the near side

Visual Targets:	Workmen and obstacles alongside the pivot point on the near side of the vehicle [VT4] Near corner of a nearside turning [VT5] Far corner of a nearside turning [VT6] Near side of vehicle [VT7] Workmen and equipment in entrance to near side turning [VT9] Leading near side corner of bucket [VT13]
Operational Blind Spots:	Workmen and equipment in entrance to turnings.
Major Postural Changes:	Driver has to rotate upper part of his body in excess of 180 degrees to see along the near side of the vehicle, especially the area encompassing the central pivot. Canopy and side of vehicle did not prevent him from leaning out of cab.
Visual Environment:	See previous table for details.

To the off side

Visual Targets:	Workmen and obstacles alongside the pivot point on the off side of the vehicle [VT3] Leading off side corner of bucket [VT8] Near corner of an off side turning [VT10] Far corner of an off side turning [VT11] Top edge of vehicle running down off side [VT12] Workmen and equipment in entrance to off side turning [VT14]
Operational Blind Spots:	A substantial area on the off side of the vehicle was obscured from the driver. Between the central pivot point to the leading off side corner of the bucket, it was possible for the driver to see only the hard hat of a 1,8 m tall workman standing erect at the side of the vehicle. The same workman standing in the area of the pivot point was totally obscured [VT3]. Below a height of 1,8 m the near and far corners of an off side turning were obscured [VT10] and [VT11]. Furthermore, any workmen or equipment in the entrance to an off side turning would have been almost totally obscured.
Major Postural Changes:	None
Visual Environment:	See previous table for details.

Deviations from Procedures:

1. When engine is running at idle speed and when the bucket is raised in its normal travelling position, output levels from the vehicle headlights were less than the specified 20 lux given in the current industry standards.
2. The vehicle observed was not fitted with a horn and the driver had no alternative audible warning device. It was therefore not possible to comply with the signalling requirements specified in the mine's transport rules.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1 Collision with pedestrians/maintenance staff	Lines of sight to front, off side and rear were obstructed. Lack of visual/audible tramming alarm systems.
2 Struck by objects thrown up by vehicle	Drivers lines of sight to front and rear obstructed Output from front headlights masked by bucket Occasional items in roadway not picked up by routine housekeeping
3 Injured whilst leaning out of cab	Cab design has minimal restraining effects Sight line and headlight restrictions create a temptation among drivers to lean out of cab.
4 Postural injuries	Fixed side seating arrangement combined with sight line and headlight restrictions create the need for drivers to undertake gross postural changes.
5 Collision with other vehicles particularly at junctions and turns	Machine lighting fails to provide adequate warning to drivers of other vehicles. Lines of sight to front, off side and rear were obstructed. Restricted roadway lighting at some junctions
6 Collision with workmen, loads and other plant at shaft station	Lines of sight to front, off side and rear were obstructed. Lack of visual/audible tramming alarm systems.
7 Collision with corners of turns on off side	Lines of sight to front, off side and rear were obstructed.

Assessment of Vehicle 5 - Battery powered scoop

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
The method of work varied considerably and it was not possible to define a clear task hierarchy. Basically the driver was required to: • Systematically drive through the different routes used by the three shuttlecars • Scoop up any spillage or accumulations of coal • Fill in any ruts by depositing material from the scoop • Grading uneven ground by inverting the scoop and using it to scrape and compress the ground. Approximately 60% of the drivers time was spent travelling in the forward direction i.e. scoop leading and 40% in reverse.	VT1 Workmen, obstacles and the roadway in the path of the vehicle VT2 Power cables for the shuttlecars VT3 Ground in front of the scoop VT4 Right hand edge of the scoop VT5 Near corner of roadways being turned into VT6 Far corner of roadways being turned into VT7 Shuttlecars and any other vehicles in the same road VT8 Ribside behind the driver	1 2 1 1 3

The visual targets identified could be grouped into two visual attention areas**,** namely, facing in a forwards (towards the scoop) and in a backwards direction (to reverse). The visual targets are however essentially the same in both directions and have, therefore, been considered collectively below.

Operational Blind Spots:	When entering off-side turnings, the driver's view of workmen, obstacles and other vehicles in the roadway was partially obscured.
Major Postural Changes:	Driver has to twist through 180 degrees to see to the rear.
Visual Environment:	
Visual angle	People, obstructions and objects in roadway at a range of 1,0m (end of m/c) to approx. 5m. Corners of turnings 5-10m from the driver Side of scoop 2m from driver Power cables lying in roadway 2-6m from driver
Illuminance-	Illumination directly in front and behind vehicle at 20m = 25 lux Illumination at ribsides 20m in front and behind vehicle = 4 lux
Reflectance-	Variable. Supervisors in white overalls, workmen in dark blue overalls. All hard hats white. Other machines painted white. Supply cables black.
Contrast-	Viewed against: Sidewall dry dull coal near working headings, stone dusted elsewhere. Floor damp but not muddy.
Visual conditions-	Poor, resulting from limited spread of light to ribsides and awkward postures that have to be adopted by the driver. Damage to off-side of vehicles indicates that collisions are not uncommon.
Classification-	Detection and course tracking
Operators comments-	Driver expressed concern about the lack of protection to his back. Bolts extending from the ribsides are difficult to detect and the protective guarding behind the driver was insubstantial.

Deviations from Procedures:
1. None.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1 Striking workmen, shuttlecars and the corners of turns on the off-side of the vehicle when travelling in either direction.	No restrictions on workmen walking along vehicle routes. Lines of sight to off-side of machine obstructed. Low reflectance and hence poor contrast/visibility of workforce due to use of dark blue overalls. Stone dusting does not keep pace with advancement of headings. Lack of effective traffic controls to prevent machine from working in roadways at same time as shuttlecars.
2 Fire, explosion, burns, etc. from damage to supply cables to shuttlecars, etc.	Visibility of power cables is poor.
3 Contact with bolts protruding from ribsides	Failure to crop protruding bolts and provide adequate driver protection

Significant Factors from Other LHDs

The assessment details given above were also substantially applicable to Vehicles 2, 3 and 4. The following additional factors were also identified:

Vehicle 2.

In the context of visibility and illumination this vehicle was very similar to the Vehicle 1. and was used for similar operations. The resulting hazards were therefore essentially the same. Driver sight lines were marginally better in that it was possible to see:

- the whole head of a 1,8m tall person standing erect in front of the bucket or behind the engine compartment rather than just the top of their hard hat.
- the whole head of a 1,8m tall person standing erect at any point on the off side of the vehicle rather than just their hard hat or not at all
- the obstacles at ground level 30m in front and behind the vehicle, rather than at 60m.

Illumination problems were similar in that:

- output levels dropped to an almost negligible value when the engine ran at idle speed
- while maximum output levels from the front headlights measured 20 lux at 20m the bucket obstructed output when raised to the normal travelling position.

An additional problem on this vehicle was that one of the rear headlights was hanging loose (pointing vertically downwards) and had, apparently, been in this condition for some period of time.

Vehicle 3.

Although Vehicle 3 was some 50cm lower than Vehicles 1 and 2, the driver was provided with a relatively higher seat. Sight lines were, therefore, marginally better in that the drivers were able to see the head and shoulders of a 1,8m tall person standing erect at any point round the periphery of the vehicle.

Maximum roadway height was 2,0m and, in the absence of a canopy, there was a significant risk of tall drivers striking objects at roof height. Drivers reported that they regularly bumped their heads against the roof. The problem was greatest when travelling forwards because the bucket prevented the headlights from illuminating the obstructions.

Some drivers adopted a crouched/leaning posture to avoid contact with the roof, which reduced their ability to identify workmen or obstacles in the path of the vehicle, and created risk of postural injuries.

The drivers raised the following issues associated with the vehicle lights, which created a significant collision risk:

- Limited provision of effective visual warnings on other moving or parked vehicles.
- When moving, the rear facing headlights operate as well as the forward facing units thereby ‘blinding’ the drivers of following vehicles.
- Several of the LHDs observed at the mine had defective headlights.

Machine 4.

The limitations outlined above for Machine 3 also apply to Machine 4. However, on this vehicle the drivers were provided with a relatively lower seated position. While this marginally reduced the risk of the operators striking their heads against the roof, sight line limitations around the vehicle were more pronounced. To overcome this limitation, the drivers developed the tendency of leaning out of the cab to enhance their view ahead when travelling.

Coal Cutting Machines

Coal cutting machines were examined in drill and blast production sections. Only one type of machine was identified and this was a wheel propelled unit that was controlled by a forward facing seated operator. Details and an assessment of a specific but typical system are given below.

Key Dimensions:

All roadways, intersections and faces in the section were 6,0m wide x 3,5m high and the pillar width was 20m.
The loader was an electrically powered machine 6-7m long x 2m wide x 1,0m high. The operator controlled the machine from a seated position in an on-board control station which was located centrally on the machine directly behind the cutter bar boom i.e. 4m from the tip of the cutter bar.
The cutter bar could be swung laterally with respect to the boom and the boom could be lifted and rolled. All of these movements were exercised when cutting. The cutter bar also had to be swung over when tramming around corners.
The loading team consisted of three men: the machine operator; the cable handler; a general assistant whose main duty involved watering down the product with a hose pipe and clearing loose coal out of the slot with a shovel.

Sources of Illumination:

Machine was fitted with Hytronic 12v 50W headlights (white) at both front and rear ends, all of which illuminate when machine was switched on regardless of travel direction selected. A pair of these units facing forwards were mounted on top of the machine immediately behind the cutter bar boom, one at each corner of the machine. A single rearward facing unit was mounted on top of the machine at the rear left corner.
Additional illumination from other machines when tramming.
Caplamp illumination from driver and cable handler and occasionally from other workmen in the section

Task Descriptions

Machine Operations - The following table considers visual targets of the machine operator only.

Task Elements	**Visual Targets of Machine Operator**	Hazard No.
Tram machine to new face		
Raise cutting bar boom	VT1 Cutting bar boom VT2 Controls	
Tram backwards out of face	VT3 Cable handler, other workmen and obstacles behind machine. VT4 Supply cables	1, 2
Reverse turn machine at intersection Swing cutter bar over Turn machine	VT1, VT2, VT3 VT4 VT5 Left sidewalls and corner of roadway and any people or obstacles along left side of machine VT6 Right sidewalls and corner of roadway and any people or obstacles along right side of machine VT7 Far wall of roadway being reversed into.	1, 2
Tram forward (straighten boom and machine)	VT1, VT2, VT5, VT6 VT8 Workmen and obstacles in front of machine	
Negotiate left and right turns	VT1, VT2, VT3, VT5, V6, VT8	
Cut right side of face		
Align machine at right side of pillar and stop	VT1, VT6, VT8	3
Align cutter bar	VT1, VT9 Floor line of face VT10 Chalk lines on face	3
Tram forward and sink cutter bar into face	VT1, VT2, VT6, VT9, VT10 VT11 Attendant with water hose.	
Cut to left and right	VT1, VT9, VT10	
Reverse to withdraw cutter bar	VT1, VT2, VT3, VT4	1, 2
Re-align machine to trim ribside	VT5, VT6	3
Sweep cutter bar over ground to level	VT2 VT12 Ground beneath cutter bar	3
Reverse machine away from face	VT3, VT4, VT5, VT6	1, 2
Clean out slot (men using shovels)	VT8 VT13 Fractures and loose conditions developing on face VT14 Fractures and loose conditions developing in roof	
Cut right side of face	Repetition of above but VT7 replaces VT8	
Tramming machine to and operation in next heading was repetition of above		

The visual targets identified above were grouped into the following four visual attention areas**:**

Visual Attention Area for Machine Operator during Tramming and Cutting Operations

Front of machine

Visual Targets:	Cutting bar boom [VT1] Machine controls [VT2] Supply cables to other machines [VT4 Workmen and obstacles [VT8] Floor line of face [VT9] Chalk lines on face [VT10] Ground beneath cutter bar [VT12] Fractures and loose conditions developing on face [VT13] Fractures and loose conditions developing in roof [VT14]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Measurements taken 1,0m off the ground in front of machine 5,0m from the light units were: 100 lux along the centre-line of the unit mounted on the front right corner of the machine 100 lux along the centre-line of the unit mounted on the front left corner of the machine With machine parked in centre of roadway, measurements taken 0,5m off the ground 20m in front of machine were: 15-20 lux on right side of roadway 15-20 lux in centre of roadway 15-20 lux on left side of roadway
Reflectance-	All workmen in white hard hats, dark blue overalls, and reflective yellow waistcoats. All other vehicles were painted white. Cutting bar was shiny metallic colour. Chalk marks on face were white although other visual targets on face were black. Supply cables were also black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate, and dust levels were low.
Classification-	Identification/course tracking
Operators comments-	Major concern was reversing into cable handler and slewing machine into attendant hosing down the cutting bar during cutting operations. Driver was dazzled by rear lights from other machines, which shone all the time regardless of whether these machines were reversing or whether rear light illumination was needed at the time.

Right side of machine

Visual Targets:	Right side walls and corners of roadway and any people or obstacles along the right side [VT6] Attendant with water hose [VT11]
Operational Blind Spots:	No definable blind spots for driver ,but when cutting his attention is divided among several different visual targets. There were, for instance, several occasions when he became oblivious to the presence of people in the working area who could have been struck by the machine because his attention was focused on the cutting bar and floor line.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. All other vehicles were painted white. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate, and dust levels were low.
Classification-	Identification/course tracking
Operators comments-	See comments above

Left side of machine

Visual Targets:	Left side walls and corners of roadway and any people or obstacles along the left side [VT5] Attendant with water hose [VT11]
Operational Blind Spots:	No definable blind spots for driver, but when cutting his attention is divided among several different visual targets. There were, for instance, several occasions when he became oblivious to the presence of people in the working area who could have been struck by the machine because his attention was focused on the cutting bar and floor line.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamp illumination from machine operator only
Reflectance-	All workmen in white hard hats, dark blue overalls, and reflective yellow waistcoats. All other vehicles were painted white. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Good, air speed was moderate, and dust levels were low after face had been prepared.
Classification-	Identification/course tracking
Operators comments-	See comments above

Rear of machine

Visual Targets:	Cable handler, other workmen and obstacles behind machine [VT3] Supply cables [VT4] Far walls of a roadway being reversed into [VT7]
Operational Blind Spots:	No definable blind spots, but area of dark shadow behind the machine to the right created problems for the driver (see illumination measurements and drivers comments below).
Major Postural Changes:	Operator had to turn whole body to see to the rear.
Visual Environment:	
Illuminance-	50 lux measured on the centre-line of the rear light unit 1,0m off the ground 5m behind the machine. (Note light unit was mounted on the rear left corner of the machine.) With machine parked in centre of roadway, measurements taken 0,5m off the ground 20m behind the machine were: 10 lux on left side of roadway 10 lux in centre of roadway 5 lux on right side of roadway
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. All other vehicles were painted white. Chain conveyor was shiny metallic colour. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Air speed was moderate and dust levels were low. Right side of roadway immediately behind the machine was in dark shadow.
Classification-	Identification/course tracking
Operators comments-	Driver considered that additional illumination should be provided to the rear of the machine i.e. similar to that provided on the front. See also comments above

Cable Handling

The cable handler had a limited number of primary visual targets that required his attention during almost all of the task elements described above for tramming and loading operations. These visual targets are tabulated below.

Visual Targets
VT_1 Supply cable
VT_2 Back of machine
VT_3 Slip/trip hazards on floor
VT_4 Machine operator - to communicate
VT_5 Other machines and obstacles behind

Visual Attention Area for Cable Handler during Tramming and Loading Operations

Visual Targets:	Supply cable VT_1 Back of machine VT_2 Slip/trip hazards on floor VT_3 Machine operator to communicate VT_4 Other machines and obstacles behind VT_5
Operational Blind Spots:	
Major Postural Changes:	Frequent bending down to handle supply cable
Visual Environment:	
Illuminance-	See previous table for illumination levels from single rear facing headlight. (With headlight covered, only light was from caplamps of cable handler and machine operator – see deviation No. 5 below).
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. This and other vehicles were painted white. Supply cables were black.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. While air speed was moderate and dust levels were generally low, illumination was poor. Rear facing light caused glare problems and left the other half of the roadway in dark shadow creating problems of adaptation.
Classification-	Identification/course tracking.
Operators comments-	Cable handler claimed that he faced unnecessary risks due to visual conditions outlined above.

Deviations from Procedures:

1 Machine operator did not use whistle when cornering, approaching people in roadway and as means of communication with shuttlecar driver.

2. Output from rear facing headlight did not fully comply with statutory 10 lux at 20m.

3. Cable handler and workmen in face were seen operating closer than minimum 3m distance from machine (cable handler apparently adopted this position when tramming to compensate for poor illumination levels.)

4 No signals were exchanged between the driver and cable handler; the cable handler was virtually ignored during cutting operations.

5. It was reported that the rear light was sometimes covered during cutting operations and when the machine was being trammed forward due to the amount of glare created.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Fire, explosion, burns, etc. caused by running over cables	Low reflectance and hence poor contrast of power cable with ground. Restricted sight lines and dark shadow behind machine.
2. Reverses into cable handler and other plant/machines	Lack of illumination behind machine predisposes the tendency for cable handler to work too close to machine when the light is covered Machine not fitted with any form of warning to denote intended reverse movement Restricted sight lines and dark shadow behind machine. Poor lighting behind machine predisposes a tendency for the cable handler to stand too close to machine.
3. Operator and other workmen crushed through inadvertent slewing of machine	No apparent restrictions on presence and movement of workmen in working area when loading Failure by workmen to maintain the regulation 3m distance from machine

Additional significant factors associated with coal cutting machines

Given the lack of mine lighting in production sections, there is an incidence of workmen tripping over the cutterbar of parked machines. Similarly, there is an incidence of other machines running over the cutter bars of parked machines.

Shearers

The South African coal mining includes longwall and shortwall operations in both thin and thick seams. The project examined several shearers operating in a representative range of these conditions. The shearers examined included units provided with fixed on-board control stations and remotely controlled units.

Assessment details for a large double ended shearing machine operating in a 3,0m high shortwall face is given below. The machine was operated from fixed on-board control stations. Incorporated within the assessment is a consideration of the shearer as an individual machine, and the face and its support system as a dynamic location. Given the highly interactive nature of shearing operations and the operation of face support lines, it was considered more beneficial to combine these two areas of consideration within a single assessment rather than isolating them in separate assessments in different areas of the report.

Following the assessment, significant factors associated with other shearer operations are summarised.

Key Dimensions: The face was nominally 3,0m in height and 110m in length. Six-leg powered roof supports were used. Most of the time the machine operators worked in the travelway (between the front and centre legs) but occasionally, when the AFC had been advanced, they worked between the front legs and the cable handler. Maximum permissible distance from centre of travelway to the face was 4,0m. Distance between cutting drum centres was approximately 10m and between the two control stations 6,0m. A uni-directional system of operation was in use, which involved cutting from maingate to tailgate in the same direction as the air movement. An on-board water supply system was used to dampen the product.

Sources of Illumination: Sylvania F13W, 20W, 0,5m long flameproof fluorescent light tubes were mounted under the canopy of the powered roof supports. From the maingate to a point half way along the face, one of these units was mounted on each support, thereafter to the tailgate they were mounted on every other support. The tubes were mounted to the underside of the canopies between the front legs of the supports and the cable trough/spillplates. Caplamps were the only other source of illumination.

Task Description

Task analysis was carried out on the two machine operators simultaneously as firstly, the machine cut from the maingate towards the tailgate and secondly, during its return to the maingate when it was use to trim and generally clean up the face. During the cutting element of the cycle, the leading operator adopted the role of main controller in that as well as controlling the leading drum, he stopped and started the machine, controlled haulage speed, etc. He adopted a position about 1m in advance of the control station almost in line with the axis of the drum in order to see the roof line but frequently had to return to the control station. The trailing operator was confined essentially to controlling the position of the trailing drum. He also adopted a position about 1m behind the control station approximately in line with the drum axis for the same reason as the leading operator. The roles of the two operators was reversed during the return cleaning out element of the cycle. Whichever direction of travel was adopted, the leading drum was used to cut the roof of the face and the rear drum the floor bench. The method used to trim out the main gate was as follows:

- The machine was taken right across the heading with the drum lowered to avoid collision with any roof bolts.
- The roof supports and AFC behind the machine were advanced.
- The machine was taken 15m along the face while the AFC in the heading was advanced.

- The machine was reversed back to square out the heading.
- The machine was then ready to commence the cutting cycle.

The visual targets of the leading and trailing operators, regardless of the direction of travel, are detailed below.

Trailing Operator	***Leading Operator***
VT1 Floor line/base of drum	*VT1 Roof line/top of drum*
VT2 Centre of face/top of drum	*VT2 Material flying from drum*
VT3 Roof (to detect loose or falling material)	*VT3 AFC 3-4 m ahead*
VT4 Leading operator	*VT4 Control panel*
VT5 Cable handler/trough	*VT5 Trailing operator*
VT6 Floor of travelway within the powered roof supports	*VT6 Cable handler/trough*
VT7 Ground between the front legs and the cable trough/spillplates	*VT7 Floor of travelway within the powered roof supports*
VT8 Roofbolts in gate end	*VT8 Water supply on to product*
VT9 Control panel	*VT9 Ground between the front legs and the cable trough*
	VT10 Roofbolts in tailgate

The visual targets of the powered roof support [PRS] teams are detailed below:
VT1 PRS control units
VT2 Items within the area of operations that might obstruct movement
VT3 People within the operational area
VT4 Position of AFC structure in relation to PRSs
VT5 Roof in front of canopies (to check condition and presence of loose/hanging material.
VT6 Loose material between canopies above travelway

The visual targets identified above were grouped into the following five visual attention areas:

Visual Attention Areas for Machine Operators

Towards the face and AFC

Visual Targets:	**Trailing Operator** Floor line/base of trailing drum [VT1] Centre of face/top of trailing drum [VT2] Unsupported roof above machine (hanging/falling material) [VT3] Roofbolts in gate ends [VT8] ***Leading Operator*** *Roof line/top of leading drum [VT1]* *Material flying from drum [VT2]* *AFC 3-4 m ahead [VT3]* *Roofbolts in gate ends [VT10]* *Water supply on product [VT8]*
Operational Blind Spots:	Dust generated by the machine travels with the airflow from maingate to tailgate. During the main cutting element of the cycle when travelling from the maingate to the tailgate, the leading operator's view of all five visual targets was almost completely obscured.
Major Postural Changes:	Both men had to work in a stooped/crouched posture to see the roof and roof line in front of the support canopies.
Visual Environment:	
Illuminance-	Measurements taken 0,5m above centre of AFC: Zero 3m ahead of machine when cutting towards the tailgate *[VT3]* 5 lux 3m ahead of machine when travelling towards maingate *[VT3]* Measurements taken adjacent to roofbolts 10m ahead of leading operator 5 lux in maingate *[VT10]* Zero in tailgate *[VT10]* It was not possible to measure lighting levels on any of the other visual targets.
Reflectance-	Minimal reflectance from white powered roof supports, cable trough and spill-plates. None from coal shearer or AFC
Contrast-	Metallic drum against face, metallic AFC against ground, machine covered in coal and coal dust. Workmen in blue overalls.
Visual conditions-	Very heavy dust generation. Water served only to dampen product and had virtually no value in suppressing dust. Machine travelled at same speed as air flow so when cutting from maingate to tailgate operators were continually enveloped in a very dense cloud of dust, which was virtually impenetrable, by any form of illumination provided.
Classification-	Course tracking
Operators comments-	Expressed particular concern about material breaking away from face and roof and being hit by material thrown up by drum.

Features on the machine

Visual Targets:	Control panel on maingate end of machine [VT9] } Leading operator Cable handler/trough [VT5] } *Control panel on tailgate end of machine [VT4] }* *Cable handler/trough [VT6] } Trailing operator* *Water supply on product [VT8] }*
Operational Blind Spots:	During cutting operations the control panel is almost obliterated from the view of the leading operator
Major Postural Changes:	Operators work in a continually stooped posture to see other visual targets
Visual Environment:	
Illuminance	With no dust make: 10 lux measure under lights 1m off the ground 5 lux measured between lights 1m off the ground When machine was running lighting levels on all above visual targets running along length of the face were not measurable.
Reflectance	See previous table
Contrast	Control panel was coated in dust and was not distinguishable from rest of machine. Black cable contrasted with white cable trough.
Visual conditions	See previous table
Classification	Identification/course tracking
Operators comments	Sometimes when face mask gets coated in dust he has to feel for the stop control

Travelway

Visual Targets:	Floor of travelway within the powered roof supports [VT6] } Leading operator Ground between the front legs and the cable trough [VT7] } *Floor of travelway [VT7] } Trailing operator* *Ground between the front legs and the cable trough [VT9] }*
Operational Blind Spots:	None
Major Postural Changes:	See previous table
Visual Environment:	
Illuminance	Measurements taken between front legs and cable trough/handler i.e. directly under row of lights: 20 lux directly under light unit 10 lux between light units at maingate end of face 10 lux between light units at tailgate end of face 10 lux in travelway within supports
Reflectance	See previous table
Contrast	Some contrast between white PRS legs. No contrast of slip/trip fall hazards (loose coal) forward of front legs.
Visual conditions	See previous table
Classification	Identification

Operators comments	Some concern about having legs and feet trapped when powered supports are advanced. During cutting, operator can be unseen by men moving supports.

Between operators (to communicate)

Visual Targets:	VT4 Leading operator *VT5 Trailing operator*
Operational Blind Spots:	During the cutting element of the cycle, the two operators were virtually obliterated from one another especially when they had to operate in front of the powered roof supports
Major Postural Changes:	See previous table
Visual Environment:	
Illuminance	See previous table for lighting measurements taken in travelway
Reflectance	See previous table
Contrast	All workmen wore blue overalls with no reflective strips, most had white hard hats
Visual conditions	See previous table
Classification	Identification
Operators comments	In worst conditions he has a problem seeing even the other operator's caplamp and could not hear shouted warnings above machine noise.

Deviations from Procedures:
Operators position themselves whenever possible adjacent to the axis of the cutting drums. This is the only position which provides them with a view of the drum and face, and in the case of the leading operator, anything ahead of the machine. This conflicts with their training and the generally accepted safe practice that requires them to maintain position at the control panel. Failure to adopt this position exposes them to the risks of being hit by material projected from the drum and falling from the roof, and reduces their ability to communicate with one another and stop the machine rapidly in an emergency.

Visual Attention Areas for PRS Operators

Visual Targets:	PRS control units [vt_1] Items within the area of operations that might obstruct movement [vt_2] People within the operational area [vt_3] Position of AFC structure in relation to PRSs [vt_4] Roof in front of canopies (to check condition and presence of loose/hanging material [vt_5]. Loose material between canopies above travelway [vt_6]
Operational Blind Spots:	Dust generated by the machine travels with the airflow from the maingate to the tailgate. This dust limits the view of all PRS workers when working downwind of the machine. During the main cutting element of the cycle, any visual targets more than 12m away from them would be virtually obscured.
Major Postural Changes:	Men had to adopt stooped posture to see roof in front of canopies
Visual Environment:	
Illuminance	See details given in previous tables for machine operators
Reflectance	See details given in previous tables for machine operators
Contrast	See details given in previous tables for machine operators
Visual Conditions	Visual conditions were very poor and were essentially the same as those previously described for the machine

	operators. It was significant, however, that at the tailgate end of the face, where dust had greatest influence on visibility, light units were provided only on alternative supports. (In contrast to every support at the maingate end where dust levels were lower).
Classification	Identification/course tracking
Operators comments	Their real concerns were trapping machine operators and other workmen obscured from their vision when advancing the supports and being hit by lumps/rocks falling between the canopies when they were lowered.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations	Initial Recommendations
1. Struck by material projected by the drum or breaking away from the face/roof.	Visibility of airborne items is low due to high dust levels Poor personal positioning resulting directly from inadequate visibility from recommended working position places operator at risk.	More effective method of dust control (see note below) to improve visibility and enable operators to work in safer position
2. Hit by roofbolts sheared off by the drum when trimming out the gate ends.	Same as for Hazard 1.	See recommendation for Hazard 1 Operator should also be required to stop shearer at entrance to gate end to allow dust to clear and check presence/position of bolts
3. Failure to stop the machine rapidly in emergency situations	Visibility of stop controls on control panels low due to high dust levels and poor conspicuity/identifying features of stop controls. Limited means of stopping machine in an emergency (no emergency stop controls provided other than those on control panel).	Recommendation for Hazard 1 will allow operators to work closer to the control stations Consideration should also be given for the introduction of a pull-chain running the length of the machine. This is a standard feature on UK machines and would allow operators to stop the machine rapidly wherever they were positioned.
4. Collision with obstructions in front of machine.	Visibility of objects in path of machine is low due to high dust levels and poor conspicuity/identifying features of stop controls. Low reflectance and hence poor contrast visibility of workforce due to use of dark overalls.	See recommendation for Hazard 1 Consider standard issue of light coloured overalls and reflective waist coats
5. Trapped by movement of powered roof support.	Visibility in travelway poor due to high dust levels Low reflectance and hence poor contrast visibility of workforce due to use of dark overalls	See recommendation for Hazard 4
6. Slip/trip/fall in travelway.	Same as for Hazard 5.	See recommendation for Hazard 1 Maintain high standards of housekeeping.
7. Workmen caught by machine during start-up.	Low reflectance and hence poor contrast visibility of workforce due to use of dark	Consider standard issue of light coloured overalls and reflective waist coats

	overalls. No pre-start alarm for drum or vehicle movement fitted	Consider introduction of pre-start warning alarm
8. Struck by lumps/rocks falling between canopies	Restricted vision particularly at tailgate end.	Increase light units at tailgate end to one unit per support

Note

The main cause of poor visibility on the face was a failure to effectively control the dust. Water from the machine was only effective in dampening the product thereby reducing dust emission problems from the outbye conveyor systems. A solution should be considered using one or a combination of the following alternatives:

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

Significant factors from other shearer operations

Thin seam operations

- Low height prevents lights from being fitted to underside of canopies. When mounted at the back of the canopies, the lights provide minimal benefit.
- From a crawling posture, face workers are unable to turn and incline their heads sufficiently to direct their caplamps at some visual targets.
- When crawling, face workers sustain injuries to their hands and knees by striking against unseen items left in the travelway such as planks, corrugated sheets, and lumps.
- Operator's view of maintenance workers is obstructed by the shearer and support legs.
- Canopies obstruct sight lines to the roof.
- Workmen using the travelway interfere with line of sight communications between the two operators.
- Spill plates and cable troughs interfere with line of sight and caplamp illumination to controls and displays.
- Visual limitations caused by dust are increased due to reduced air flow through the face.

Remotely Controlled Shearers

Sight line requirements for the operators of remotely controlled shearers are virtually the same as those required by operators of shearers provided with on-board control stations. 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 on-board control 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, the remote control systems on the machines examined provide both drivers with the freedom to adopt a wide range of operating positions which enables them to overcome the visual limitations associated with fixed on-board control arrangements. Unobstructed sight lines to practically all the visual targets can be obtained within a 15m operational range of a remote control station. There are however visual limitations associated with remote control, for example:

1. The operating ranges on some controllers are too great to ensure the safety of men working around the machines.
2. In utilising freedom to adopt the most visually advantageous position:
    - operators can place themselves in a potentially unsafe position e.g. adjacent to the drum where there is an increased risk of being struck by material projected by the drum.
    - the two drivers can become visually detached from one another thereby jeopardising effective communications.
    - Operator's view of important displays on the machine can become obscured.

Tractors

A wide range of tractors are used, ranging from small two-wheel-drive units, where the drivers sit low down at the back between 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 used essentially as general utility vehicles for towing a variety of sleds and trailers.

Assessment details are given below for a small two-wheel-drive unit towing a sled since there tends to be more visually related problems associated with this combination of equipment. The assessment deals with a specific but typical operation.

Following the assessment, the significant factors associated with tractors and trailers and tractors in general are summarised.

Operation: The tractor observed returning from a production section, undertaking a three point turn in the tractor road, reversing up to and coupling on to a sled loaded with a large electrical control panel and setting off back to the section. The sled had previously been dragged from a loading station by a similar tractor and left parked at the side of the tractor road. Workmen involved in the operation included the tractor driver and an assistant who made the coupling.

Key Dimensions: Roadway section 6,0m wide x 2,5m high. Tractor was approx. 3m long x 1,8m wide
Driver sat with his back against a high bulkhead near the rear of the tractor and faced forward.
Travel distance to the section was approx. 2km

Sources of Illumination: Machine was fitted with twin white headlights at the front and one white headlight at the rear type Hytronic 6751 (12v 50W). The front lights were rigidly mounted approx. 1,3m off the ground, one at each side of the machine, with beams aimed directly ahead. The single rear light was rigidly mounted low down on one side aimed directly into the ground. All lights operated when the machine was switched on regardless of travel direction.

Twin 1,8 m 75W fluorescent tubes suspended in the centre and laterally across the roadway 0,5m from the roof spaced at 20 m intervals illuminated the tractor road.

Additional illumination was provided by caplamps of the driver and assistant.

Task Description

Task Elements	Visual Targets	Hazard No.
Travel outbye from section	VT1 Ground/people/obstacles/other vehicles in front of the tractor	3
Three-point turn in roadway	VT1 VT2 Ground/people/obstacles/other vehicles behind the tractor VT3 Ground/people/obstacles/other vehicles to the right of the tractor VT4 Ground/people/obstacles/other vehicles to the left of the tractor	1 & 2
Reverse to loaded sled	VT5 Assistant holding coupling bar.	1
Assistant couples sled to tractor (simultaneously with above)	*VT6 Tractor driver*	*1 & 4*

	VT7 Coupling point on tractor *VT8 Rear wheel of tractor*	
Travel inbye to section.	VT1, VT2	3

The visual targets identified above were grouped into the following visual attention areas**:**

Visual Attention Areas for the Driver

Right, left front and rear of machine

Visual Targets:	Ground/people/obstacles/other vehicles in front of the tractor [VT1] Ground/people/obstacles/other vehicles behind the tractor [VT2] Ground/people/obstacles/other vehicles to the right of the tractor [VT3] Ground/people/obstacles/other vehicles to the left of the tractor [VT4] Assistant holding coupling bar (to communicate) [VT5].
Operational Blind Spots:	The ground behind the tractor was obscured to a distance of approx. 15m by the high bulkhead behind the driver's seat. Hidden within this blind spot is the assistant (and sled coupling unit) who has to communicate with the driver by shouting.
Major Postural Changes:	Driver has to twist through 180 degrees to see behind. During coupling operations he levers his body off the seat to overcome sight line limitations
Visual Environment:	
Visual angle	People and obstructions at a range closing from 20m to 0,5m (from extremity of m/c).
Illuminance-	Tractor lights (engine running above idle speed): Front: 4 lux at 20m directly in front of tractor 1,5 lux at 20m (average across roadway) Rear: Not measurable at 20m With engine running at idling speed, light levels were not measurable. Roadway lights - measurements taken 1m off the ground: Directly beneath: 32 lux centre of road, 12 lux (left), 28 lux (right) looking inbye Between lights: 25 lux centre of road, 8 lux (left), 12 lux (right) looking inbye
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. Tractor and sled was painted white but other tractors seen were blue.
Contrast-	Viewed against stone dusted ribsides with poor reflective characteristics. Ground was dry compacted coal dust.
Visual conditions-	Poor. Machine lights extinguish at low engine revs Roadway lights are covered in dust and emit only a fraction of their potential output.
Classification-	Detection, identification and course tracking
Operators comments-	Driver expressed concern about restricted sight lines and level of illumination provided for reversing operations. A mine official stated that the single reversing light had been angled down to minimise glare problems when reversing.

Visual Attention Areas for Assistant

Visual Targets:	*Tractor driver (to communicate) [VT6]* *Coupling point on tractor [VT7]* *Rear wheel of tractor [VT8]*
Operational Blind Spots:	Assistant is unable to see the driver during coupling operations and has to signal by shouting.
Major Postural Changes:	None
Visual Environment:	
Visual angle-	Rear of tractor at a range of 0,4m. Coupling point on rear of tractor was approx. 0,3m at a distance of 0,4.
Illuminance-	See previous table for details of tractor headlights and roadway illumination levels. 90 lux on tractor coupling pin from reversing light. Assistant's body shields coupling from any measurable light levels from roadway lights.
Reflectance-	All workmen in white hard hats, dark blue overalls and reflective yellow waistcoats. Tractor and sled was painted white but other tractors seen were blue.
Contrast-	Viewed against stone dusted ribsides with poor reflective characteristics. Ground was dry compacted coal dust.
Visual conditions-	Poor: Machine lighting of only moderate benefit. See previous comments on roadway lights.
Classification-	Detection/identification
Operators comments-	Assistant indicated his concern about being trapped/hit by tractor when coupling sleds and trailers.

Deviations from Procedures:

1. Output levels from tractor lights did not comply with the minimum values specified in the Minerals Act.

<u>Potential Hazards</u>

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Tractor strikes and traps workmen while reversing. Assistant is at particular risk during coupling operations.	Major blind spot behind tractor. Damaged wing mirror further restricts rear view. Limitations on vehicle control due to adverse driving postures adopted to overcome sight line restrictions. Limitations in the provision, location and maintenance of tractor illumination. Limited illumination levels from mine lighting Vehicle horns/whistles not always provided and not reliably used. On some tractors glare from rear light obfuscates assistant view of potential trapping/collision points.
2. Tractor collides with items of plant while reversing, causing injuries to driver/damage to equipment	All the above listed control limitations also apply to this potential hazard

3. Collision with other vehicles approaching from behind when moving off from the side of the roadway	Major blind spot behind tractor. Lack of directional indicators. Damaged wing mirror further restricts rear view. Limitations in the provision, location and maintenance of tractor illumination. Vehicle horns/whistles not always provided and not reliably used.
4. Assistant traps hand during coupling operation	See limitation listed for Hazard 1.

Significant factors associated with towing trailers

Trailers are different from sleds in that, by having wheels and a steering axle they need to be reversed to change direction. Some of the trailers were too heavy to be turned around by hand tramming, especially when laden. Tractors were therefore used to turn them, which usually involved driving into a convenient turning and then backing out to face the opposite direction. The above assessment identified the hazards associated with reversing a tractor on its own due to the major blind spot and limitations in the standards of lighting to the rear, etc. When trailers were being reversed, the risk of striking and trapping workmen was increased for the following reasons:

1. No lights were proved on the tail end of trailers
2. Loads carried on the trailers masked the rear lights of the tractor which reduced both driver visibility and the effect that the lights might previously have had in warning pedestrians of the tractors approach.

Significant factors associated with tractors in general

- The mines commonly adopted a policy of fitting two forward facing headlights and one rearward facing headlight to their tractors. Some of the front headlights were defective and tractors were seen in use with only one of them operable. Furthermore, there was no standard position for the rear light and their location varied considerably across the tractors in use. Given this situation, the policy to use only white lights (white and red lights are rarely used to denote travel direction) and the use of a system whereby all the tractor lights came on together when the tractor engine ran, pedestrians often became confused as to which direction tractors were moving in and allowed them to get very close before they ‘dodged’ out of the way.
- Headlight output diminishes at low engine speeds.
- Lines of sight to the rear of the tractors are often obstructed by wheel arches and rear bulkhead.
- Drivers experience postural difficulties looking to the rear.
- It is sometimes necessary for the drivers to raise themselves from their seat to improve their view when reversing up to sleds and trailers.
- There was a general lack of effective visual warnings on moving or parked tractors, sleds and trailers.
- Glare from the rear lights on some tractors ‘dazzled’ assistants involved in coupling and uncoupling operations.
- Illumination levels in some tractor roads, particularly at crossings, were inadequate.
- Driver’s view of passengers climbing in and out of personnel carriers was obscured.

Light delivery vehicles (LDVs)

A wide range of LDVs are used on the mines. These units are essentially adaptations of conventional ‘bakkies’ or ‘pick-ups’ used on public roads and typically comprise a cab for a driver and passenger and an open back fitted with platform seats. The vehicles examined ranged from standard production built units to special purpose custom built machines. The units are mainly used to transport small groups of workmen in and out of the mines.

Assessment details for two vehicles are given below.

Vehicle 1.

Operation: The vehicle was observed while taking a number of officials into the mine. The travel route included entry into the mine down an inclined shaft, followed by a 10km drive along a main roadway where the assessment was undertaken.

Key Dimensions: Roadway section was 7,0m x 2,5m although in places the height was down to less than 2,0m (lower than the height of the cab). Height was also reduced in places by overhead structures such as conveyors, service ranges, etc. In some places the roadway width was reduced to 3,0m and robot systems were in operation to prevent collisions. The roadway passed through old board and pillar workings and there were numerous 90 degree left and right turns and interconnecting roads. A considerable number of people were seen walking and on bicycles in the roadway. In addition to people, a number of other vehicles were seen being driven along the roadway including land cruisers, LHDs, tractors and trailers.

Sources of Illumination: Roadway Lighting:
A single row of luminaries were provided to one side of the roadway with each unit oriented in line with the roadway. The light units were twin 2,4 m fluorescent tubes. The lights were spaced so that they were located in the centre of the pillars. Illumination levels were:
45 lux measured in the centre of the roadway adjacent to a light unit.
5 lux measured in the centre of a junction

Vehicle Lights:
The vehicle was fitted with two forward facing headlights and a single rearward facing headlight. The front lights were mounted 0,5m apart and 1m off the ground. The rear light was mounted centrally 1m off the ground. All three lights were supplied by Colliery Electrical Services PTY and were flameproof units type M1 N1. The rear lights were not automatically switched to operate only when reverse travel was selected; they operated all the time.

Task Description

Task Elements	Visual Targets	Hazard No.
Set off forwards from shaft station	VT1 Ground in front of vehicle up to a distance of 5m and any plant, equipment or personnel within this area. VT2 Roof of roadway in front of vehicle up to a distance of 5m.	
Travel along straight	VT1 & VT2 VT3 Ground sides and roof of roadway in front of vehicle from 5m	1, 2, 3, 4, 5

	up to a distance of 20m and any plant, equipment or personnel within this area.	
Make turns to right	VT4 Both corners of roadway being turned into (right) VT5 Workmen and equipment in entrance to turning (right)	1, 3, 4, 5
Make turns to left	VT6 Both corners of roadway being turned into (left) VT7 Workmen and equipment in entrance to turning (left)	1, 3, 4, 5
Negotiate narrow section of roadway (Robot control initiated by activating into strap switch hanging from roof)	VT1 & VT2 VT8 Robot control VT9 Right side of roadway in front of vehicle up to a distance of 5m. VT10 Left side of roadway in front of vehicle up to a distance of 5m.	1, 3, 4
Steer past obstruction in roadway	VT1, VT2, VT9, VT10 VT11 Right side of vehicle VT12 Left side of vehicle	3
Undertake three-point turn	VT1, VT2, VT9, VT10, VT11, VT12 VT13 Ground behind vehicle up to a distance of 5m and any plant, equipment or personnel within this area. VT14 Roof of roadway behind vehicle up to a distance of 5m.	5

In addition to the above, the following three additional visual targets commanded the drivers attention throughout the activity:

VT15 Passengers seated in the rear of the vehicle
VT16 Instruments on the dashboard
VT17 Roadway signs

The visual targets identified above were grouped into the following four visual attention areas:

Looking forwards (includes making right and left turns)

Visual Targets:	Ground and roof in front of vehicle up to a distance of 5m and any plant, equipment or personnel within this area [VT1] & [VT2] Ground sides and roof of roadway in front of vehicle from 5m up to a distance of 20m and any plant, equipment or personnel within this area [VT3]. Corners of turnings and any workmen or equipment in entrance to turnings to the right and left [VT4] to [VT7] Robot controls [VT8]. Right and left sides of roadway in front of vehicle up to a distance of 5m [VT9] & [VT10] Instruments on dashboard [VT16] Roadway signs [VT17]
Operational Blind Spots:	None apart from an area of ground extending approximately 1m in front of the vehicle
Major Postural Changes:	None

Visual Environment:	
Illuminance-	Vehicle lighting: Measurements taken 1m off the ground 20m in front of the vehicle with engine running above idle speed. 10 lux in centre of road 5 lux at side of road With engine running at idle speed output levels were not measurable at 20m.
Reflectance-	All workmen wore blue overalls without any reflective strips, most had white hard hats but some were green. Most other vehicles were painted white but some trailers were blue. Overhead structures and equipment suspended from roof were generally dark painted
Contrast-	Viewed against - Main roadway ribsides were coated with stone dust with variable reflective properties. Floor was dry compacted coal dust lightened in colour at the sides by the presence of stonedust.
Visual conditions-	Mine issues: On average one in four of the roadway lights were defective. In some places up to five consecutive lights were defective. With roadway lights mounted in the centre of pillars, crossings, from which both pedestrians and other vehicles frequently emerged, were left in dark shadow. Some warning and direction signs were none reflective and were difficult to read until very close. No warning signs were provided where roof height was lower than cab height At the inbye end of the roadway the presence of ground water concealed deep ruts and items which were sometimes thrown up by the vehicle wheels. Vehicle issues: Vehicle lights extinguished at low engine revs. Windscreen was frequently covered in mud or condensation but vehicle had no wash/wipe facility None of the vehicles seen were fitted with brake lights left/right indicators or reflectors. Drivers were unable to use caplamps due to reflections from windscreens and were therefore unable to read instruments on dashboard. Headlights were badly aligned and could not be re-adjusted.
Classification-	Identification and course tracking
Operators comments-	When travelling along the roadway drivers expressed a difficulty in continually having to adapt to changing light conditions. They were particularly concerned about hitting people and other vehicles lost in the deep shadow between light units, especially when emerging from side roads. They were also concerned about striking the roof of the roadway (in places they have to steer around low points).

Looking to the right

Visual Targets:	Along the right side of the vehicle [VT11]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	See details given above for the forward visual attention areas.

Looking to the left

Visual Targets:	Along the left side of the vehicle [VT12]
Operational Blind Spots:	The left wing mirror was damaged and therefore the left side of the vehicle was obscured from the driver. When driving up close against objects on the left the driver had to estimate the amount of available operating clearance. This created difficulties when reversing and was the cause of a number of minor collisions.
Major Postural Changes:	None
Visual Environment:	See details given above for the forward visual attention areas.

Looking to the rear

Visual Targets:	Ground and roof immediately behind the vehicle up to a distance of 5m and any plant, equipment or personnel within this area [VT13] & [VT14] Passengers seated in back of vehicle [VT15]
Operational Blind Spots:	Anyone crouching behind the vehicle would be obscured from the driver Roof of roadway behind vehicle
Major Postural Changes:	Driver elected to turn and look over his shoulder rather than rely on use of central and right wing mirrors.
Visual Environment:	.
Illuminance	Vehicle lighting: Measurements taken 1m off the ground 20m behind the vehicle with engine running above idle speed 4 lux in centre of road 2 to 3 lux at side of road With engine running at idle speed output levels were not measurable
Reflectance **Contrast** **Visual conditions** **Classification**	See details as given above for forward visual attention areas.

Deviations from Procedures:

1. When engine is running at idle speed output levels from the vehicle headlights were less than the specified 10 lux given in the current industry standards.
2. Horn fitted to the vehicle was defective and there was no substitute audible warning device.
3. Vehicle was driven at speeds that considerably exceeded the maximum speed limits which exacerbated the visual limitations detailed above (max. speed limit was 20 kph, but vehicle was driven at 40 kph for most of the time).
4. Tractors, tractor/trailer units and LHDs were observed being driven without any form of rear lighting.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations** See descriptions below
1. Collision with pedestrians and workmen on bicycles	1, 3, 4
2. Collision with vehicles emerging from side roads	2, 3, 4, 5
3. Collision with parked or slow moving vehicles and other plant	3, 4, 5
4. Collision with roof or items located in the roof of the roadway	3, 4, 6
5. Items thrown up by wheels of vehicle	3, 7
6. Collision with pedestrians when reversing.	8

Description of Control Limitations

1. Low reflectance and hence poor contrast visibility of workforce wearing dark blue overalls without reflective strips.
2. Vehicle lighting fails to provide adequate warning to other drivers.
3. Windscreen condition reduces headlight effectiveness.
4. Dark areas created at critical points by arrangement of roadway lights.
5. Conspicuity of some vehicles limited by their colour contrast with background and absence of rear lighting systems/reflectors.
6. No restricted headroom warnings provided
7. Visibility of loose items in roadway concealed by ground water
8. Safety of people working behind vehicle at risk through lack of reverse warning.
9. Some warning and direction signs were non-reflective and were difficult to read from a distance.

Machine 2

This vehicle was assessed at a different mine to Vehicle 1. However, in the context of visibility and illumination, this vehicle and the conditions in which it operated were similar to those detailed in the previous assessment. The resulting hazards were therefore primarily the same. Therefore, to avoid duplicating much of the data presented above, a brief assessment highlighting the significant factors associated with this vehicle above is given below:

Roadway lighting:
Roadway lighting was considerably better than in the previous assessment in that while the same 2,4 m twin fluorescent strip lights were used, they were spaced every 15m laterally across the centre of the roadway. With this arrangement, the areas of dark shadow at cross-cuts were virtually eliminated thereby reducing the risk of collisions. Measurements taken 1m off the ground in the centre of the roadway were 150 lux directly under the lights and 35 lux mid-point between the lights.

Conspicuity of workforce:
Most workmen in this mine wore white overalls with prominent reflective strips and white hard hats further minimising the hazard risk. Some however wore blue overalls and were difficult to identify unless they were directly under lights

Vehicle issues:
The following series of limitations were identified with the vehicle

- There was no windscreen fitted with the result that driver's safety glasses (when worn) were continually covered in dirt, which considerably impaired his vision.
- Vehicle lights extinguished when engine ran at idle speed
- Vehicle was not fitted with brake lights, left/right indicators or reflectors
- Twin front headlights produced a maximum light reading of 5 lux at 20m which is less than the regulatory requirements
- Only one of the two rear lights was operative providing a light reading of 3 lux at 20m which is less than the regulatory requirements
- Headlight fixings were loose with the result that the lights 'flopped around' while the vehicles were driven

Other vehicle/machine related issues:
Numerous tractors and trailers and other personnel carriers were seen parked up at the side of the roadways without any reflectors or reflective warning signs.

Roadway conditions:
Ground conditions were better than in the previous assessment and stone dusting had been applied more systematically - which reduced hazard potential. However, very few of the signs posted in the roadways were of reflective material and were difficult to see. These included emergency signs depicting obstacles and areas where headroom was restricted, which needed to be read by drivers while the vehicles were in motion.

Multi-purpose vehicles (MPVs)

A range of MPVs are used on the mines ranging from the more common low-profile units, where the drivers are provided with a forward facing seat in a cab located centrally on the right side of the vehicle, to the less common higher-profile units, where the drivers are located centrally on the vehicle. The rear trailer units are joined by pivots to the forward tractor units to provide the vehicles with a considerable degree of manoeuvrability. The different types of unit were examined transporting a variety of detachable loads including container units, skips, stone dusters, portable miner's boxes, personnel carriers, etc.

Assessment details are given below for a low-profile unit engaged in attaching a large container, transporting it into the mine and detaching it.

Key Dimensions:

The operators sat in a cab on the right side of the engine compartment facing forwards. The cab was approximately 2,0m from the front of the vehicle and 4,5m from the rear end. Height of the vehicle over the engine compartment was 1,5m. The seated eye height of a small driver was 1,55m i.e. this driver would just be able to see over the top of the machine.

The roadway sections in which the assessment was undertaken were 7,0m x 1,8-2,0m

Sources of Illumination:

Two 50mm diameter x 50W headlights were mounted at each front corner of the vehicle 0,8m off the ground.

A single 50mm x 50W taillight was mounted on the end of the tractor unit on the right (cab) side of the vehicle. The light was angled downwards to illuminate the trailer cradle arms and anchor points.

All three lights illuminate when the engine is running regardless of the selected travel direction.

There were no lights or reflectors provided on the end of the trailer or any of the unit loads observed at the mine.

Roadway illumination was provided by 2,4m, 75W fluorescent tubes mounted laterally across the roadway every 25m. Many of the lights were defective and in some areas they were heavily coated in coal dust.

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Attach container		
Reverse to container	VT1 Workmen and obstacles alongside the pivot point on the off-side. VT2 Workmen and obstacles alongside the pivot point on the near-side. VT3 Workmen and obstacles directly in front of and to the sides of the trailer.	1,7
Align vehicle with container	VT4 Clearance between container and trailer cradle arms.	
Lower trailer to attach		
Reverse to and secure container to trailer	VT3 VT5 Trailer anchor points	1,7
Travel inbye to section		
Raise trailer to transport	VT6 Clearance between container and roof.	8
Set off	VT1 & 2 VT7 Workmen and obstacles directly in front of the vehicle.	1

Travel along straights	VT1, 2, 6 & 7 VT8 Workmen and obstacles (ground/sides/roof) far enough in front of the vehicle for them to be detected and identified to enable the vehicle to be stopped before collision.	2, 8
Negotiate near-side (right) turns	VT9 Near corner of roadway being turned into. VT10 Far corner of roadway being turned into. VT11 Near-side of vehicle. VT12 Leading off-side corner of vehicle. VT13 Workmen and equipment in entrance to turning.	2
Negotiate off-side (left) turns	VT14 Near corner of roadway being turned into. VT15 Far corner of roadway being turned into. VT16 Top edge of vehicle running down off-side. VT17 Leading near-side corner of vehicle. VT18 Workmen and equipment in entrance to turning.	2, 3, 4
Detach container		
Reverse into near-side turn	VT6 & 13 VT19 Workmen and obstacles directly ahead of the reversing trailer. VT20 Clearance between trailer and near corner of roadway being turned into. VT21 Clearance between trailer and far corner of roadway being turned into.	1, 2, 5, 6, 8
Reverse into off-side turn	VT6, 13 & 14 VT22 Clearance between trailer and near corner of roadway being turned into. VT23 Clearance between trailer and far corner of roadway being turned into.	1, 2, 3, 4, 5, 6, 7, 8
Lower trailer to detach		
Drive forward	VT7	

MPV operations at the mine varied considerably, however, most comprised various combinations of the task components identified above.

The visual targets identified above were grouped into the following visual attention areas:

Visual Attention Area Facing Forwards

Visual Targets:	Workmen and obstacles directly in front of the vehicle [VT7] Workmen and obstacles sufficiently far enough in front of the vehicle for them to be detected and identified to enable the vehicle to be stopped before collision [VT8].
Operational Blind Spots:	The engine obscured the driver's view towards the left side of the roadway. A small driver would just be able to see the head of a small workman standing erect directly in front of the vehicle.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	With the vehicle parked in the centre of the roadway, headlights provided 8,5 lux 20m ahead of the vehicle. This value was measured 1,0m above the ground at points right across the roadway. Roadway lights - measurements taken 1,0m off the ground. Directly beneath light: 200 lux in centre of road Between lights: 40 lux in centre of road Beneath a defective light:: 5 lux.
Reflectance-	Workmen wear dark blue overalls with no reflective strips. Hard hats varied in colour -white, dark blue, dark green, etc. Most vehicles were painted white but some tractors were painted blue. None of the vehicles on the mine were fitted with reflective material. Similarly, the roadway signs were not reflective and some were difficult to read while the vehicle was in motion.
Contrast-	Viewed against - Main roadway walls were coated with stone dust with poor reflective properties; floors generally were dark grey compacted coal.
Visual conditions-	Variable; machine lights extinguish at low engine revs, some roadway lights were missing, and others only emitted a fraction of their potential output. Some critical areas, such as junctions and turns into which the vehicle had to be reversed, were not illuminated.
Classification-	Identification and course tracking
Operators comments-	None

Visual Attention Area to the Near-side

Visual Targets:	Workmen and obstacles along side the pivot point on the near-side [VT2] Near corner of a roadway being turned into on the near-side [VT9] Far corner of a roadway being turned into on the near-side [VT10] Along the near-side of the vehicle [VT11] Workmen and equipment in entrance to turnings on the right [VT13] Leading corner of vehicle on the near-side [VT17] Clearance between trailer and near corner of turning being reversed into on the near-side[VT20] Clearance between trailer and far corner of turning being reversed into on the near-side [VT21]
Operational Blind Spots:	None
Major Postural Changes:	When looking towards the rear, drivers had to twist round to their right and tended to lean out of the cab.
Visual Environment:	
Illuminance-	Some light from the taillight was reflected from the face of the container, however this was sufficient only to illuminate a small area behind the operator and was of little benefit. Details of the mine lighting are given in the table of data covering the forward visual attention area.
Reflectance-	Workmen wear dark blue overalls with no reflective strips. Hard hats varied in colour –white, dark blue, dark green, etc. Most vehicles were painted white but some tractors were painted blue. None of the vehicles on the mine were fitted with reflective material. Similarly, the roadway signs were not reflective and some were difficult to read while the vehicle was in motion.
Contrast-	Viewed against: Main roadway walls were coated with stone dust with poor reflective properties, floors generally were dark grey compacted coal.
Visual conditions-	Variable; machine lights extinguish at low engine revs, some roadway lights were missing, and others only emitted a fraction of their potential output. Some critical areas, such as junctions and turns into which the vehicle had to be reversed, were not illuminated.
Classification-	Identification and course tracking
Operators comments-	None

Visual Attention Area to the Off-side

Visual Targets:	Workmen and obstacles along side the pivot point on the off-side [VT1] Leading corner of vehicle on the off-side [VT12] Near corner of a roadway being turned into on the off-side [VT14] Far corner of a roadway being turned into on the off-side [VT15] Top edge of vehicle running down off-side [VT16] Workmen and equipment in entrance to turnings on the left [VT18] Clearance between trailer and near corner of turning being reversed into on the off-side[VT22] Clearance between trailer and far corner of turning being reversed into on the off-side [VT23]
Operational Blind Spots:	The engine obscured the driver's view towards the off-side of the roadway. A small driver would just be able to see the head of a small workman standing erect directly at the side of the vehicle.
Major Postural Changes:	When looking towards the rear, drivers had to twist round to their left and stretch up to see over the top of the vehicle.
Visual Environment:	
Illuminance-	The machine lights did not provide any useful illumination to the off-side. Details of the mine lighting are given in the table of data covering the forward visual attention area.
Reflectance-	Workmen wear dark blue overalls with no reflective strips. Hard hats varied in colour -white, dark blue, dark green, etc. Most vehicles were painted white but some tractors were painted blue. None of the vehicles on the mine were fitted with reflective material. Similarly, the roadway signs were not reflective and some were difficult to read while the vehicle was in motion.
Contrast-	Viewed against - Main roadway walls were coated with stone dust with poor reflective properties; floors generally were dark grey compacted coal.
Visual conditions-	Variable; machine lights extinguish at low engine revs, some roadway lights were missing, and others only emitted a fraction of their potential output. Some critical areas, such as junctions and turns into which the vehicle had to be reversed, were not illuminated.
Classification-	Identification and course tracking
Operators comments-	None

Visual Attention Area to the Rear

Visual Targets:	Workmen and obstacles directly in front of and to the sides of the trailer [VT3} Clearance between the container and trailer cradle arms [VT4] Trailer anchor points [VT5] Clearance between container and roof [VT6]
Operational Blind Spots:	Without a load, the drivers rear view was unobstructed except for an area towards the off-side. With the container loaded, the driver's view beyond the container was completely obscured.
Major Postural Changes:	When looking to the rear, drivers had to twist round 180º to either their right or left. When turning to their right they tended to lean out of the cab.
Visual Environment:	
Illuminance-	The single taillight effectively illuminated the cradle arms of the trailer. Values of 50 lux were recorded at the load anchor points. There was however, no light transmitted beyond the trailer to facilitate reversing when carrying a load. Details of the mine lighting are given in the table of data covering the forward visual attention area.
Reflectance-	Workmen wear dark blue overalls with no reflective strips. Hard hats varied in colour -white, dark blue, dark green, etc. Most vehicles were painted white but some tractors were painted blue. None of the vehicles on the mine were fitted with reflective material. Similarly, the roadway signs were not reflective and some were difficult to read while the vehicle was in motion.
Contrast-	Viewed against: Main roadway walls were coated with stone dust with poor reflective properties, floors generally were dark grey compacted coal.
Visual conditions-	Variable; machine lights extinguish at low engine revs, some roadway lights were missing, and others only emitted a fraction of their potential output. Some critical areas, such as junctions and turns into which the vehicle had to be reversed, were not illuminated.
Classification-	Identification and course tracking
Operators comments-	Commenting on the above limitations, the drivers expressed concern over driving into people when reversing. They felt that some consideration should be given to the provision of rear lights on some transportable units such as personnel carriers, tool boxes, miners' boxes, etc. In particular, the feasibility of plugging the units to the electrical system on the tractor units should be examined.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Collision with pedestrians and obstacles when moving off, particularly in reverse	Restricted sight lines along the off-side. The container completely obstructs the driver's view of the roadway when reversing. Lack of reverse tramming alarm and warning lights on the rear of the trailer/container. Uneven ground, obscured from the driver, creates miss-alignment difficulties when reversing on to loads resulting in collision damage.
2. Collisions with pedestrians and vehicles emerging from side roads, particularly on the off-side	Sight lines restricted by the engine covers and air receiver. Limited provision of effective visual warnings on other moving or parked vehicles. Inadequate mine lighting at junctions; also a failure to clean and replace damaged lights.
3. Collision with the corners of turnings on the off-side.	Line of sight restrictions towards the front off-side.
4. Collisions with pedestrians and obstructions when entering turnings on the off-side	Line of sight restrictions towards the front off-side. Limited provision of effective visual warnings on other moving or parked vehicles.
5. Collisions with pedestrians and obstructions when reversing into turnings on either side of the roadway.	The container completely obstructs the driver's view of the roadway in advance of the unit when reversing. Lack of reverse tramming alarm and warning lights on the rear of the trailer/container.
6. Drivers injured leaning out of cab	The forward facing posture combined with spatial limitations in the cab, sight line restrictions, and inadequate levels of illumination, create the temptation to lean out of the cab.
7. Workmen caught in the off-side pivot point when vehicle articulates.	Restricted lines of sight and limited illumination
8. Workmen injured by falling roof or equipment dislodged by container	Lack of rearward illumination and the difficult postures that have to be adopted by the drivers when turning to look to the rear, restricts their view of the clearance between the load and the roof.

Significant factors from assessments of other MPVs

The visual limitations identified in the above assessment were commonly identified during examinations of other MPV operations. The following additional limitations were also identified:

- Defective headlights were identified on some vehicles.
- Some MPV operations were conducted without there being any form of audible or visual tramming alarms in evidence.
- Drivers of some vehicles were unable to detect potholes, particularly on the off-side, with the result that trailers swerved uncontrollably.
- Illumination from the taillights on some tractor units reflect back from containers and create glare problems for the drivers.
- Drivers in some low-height roadways slump below the height of the engine covers to gain more protection, thereby obliterating their line of sight to the off-side and further limiting their forward visibility.
- The driver's view of passengers boarding and alighting personnel carriers is totally obscured.
- The design of some protective canopies further restricts the driver's view of clearance between loads and the roof.

Locomotives (locos)

Locomotives are used to transport men and materials. Assessments details for the following two types of loco are given below.

1. 25T engine powered loco provided with a one-man cab at each end, so that by changing cabs, the drivers were always able to face the direction of travel.
2. 18T engine powered loco provided with a single two-man cab at one end wherein the drivers had a swivelling seat, which again enabled them to always face the direction of travel.

Loco 1. 25T unit

Key Dimensions: The loco measured 4,0m long x 1,8m wide x 1,6m high. The two driver cabs were located on the left leading-end corners of the loco. Drivers sat in the leading cab facing forwards, and assistant drivers sat in the rear cab facing backwards. The cabs (and windscreens) extended only half way across the loco. There was no communication system linking the driver with the guard. The loco was used to pull mancarriages and materials cars.

The tunnels through which the train operated were 7,0m x 2,0m in section.

Sources of Illumination: Three 12v, 50W, 50mm diameter, Lohuis halogen lamps were mounted on each end of the loco. The lights were mounted close together in a central column near the top of the loco. One light in each column was painted red. All lights at both ends operated when the engine was running.

Mine lighting varied considerably throughout the length of the haulage and at the rail stops. Long stretches of tunnel were unlit, however ,in places mine lighting was provided by twin 2,4m, 75W fluorescent light units spaced at 25m intervals. (See assessment of static locations for typical lighting provision at rail stops).

Hierarchical Task Description

The task analysis was carried out on driver activities during man-riding operations.

Task Elements	Visual Targets	Hazard No.
Prepare train for inbye journey	VT1 Shunters, drivers assistant, other workmen and obstacles directly in front of the loco to be detected before moving off.	
Drive loco in outbye direction	VT2 Workmen and obstacles sufficiently far enough in advance of the loco to enable them to be detected and the loco stopped before collision.	2, 3, 5, 7, 8
Couple up to empty mancarriages and connect air brakes	VT3 Switches on the track ahead.	4
Drive inbye and stop at rail stop	VT4 Signals and robots ahead of the loco. VT5 Couplings and shunters working directly in front of the loco.	2, 3, 5, 7, 8
Wait until boarding has been completed	VT6 Track conditions ahead of the loco. VT7 Along the sides of the train to check the safety of passengers alighting and boarding.	1, 6
Transport men inbye (following steps repeated until train reaches the final inbye rail stop)	VT8 Along the sides of the train to check the security of loads and the	

	rolling stock.	
Drive train inbye and stop at next rail stop. This involves: Stopping and changing switches Stopping at tractor road intersections	VT9 Assistant/guard – to communicate.	1 2 3 5 7 8
Wait until alighting has been completed	VT10 Cab displays.	1 6
Prepare loco for next operation		
Uncouple loco from empty carriages and disconnect air brakes		4

The visual targets identified above were grouped into the following two visual attention areas.**:**

Visual Attention Area in the Forward Direction

Visual Targets:	Shunters, drivers assistant, other workmen and obstacles directly in front of the loco to be detected before moving off [VT1] Workmen and obstacles sufficiently far enough in advance of the loco to enable them to be detected and the loco stopped before collision [VT2]. Switches on the track ahead [VT3]. Signals and robots ahead of the loco [VT4]. Couplings and shunters working directly in front of the loco [VT5]. Track conditions ahead of the loco [VT6]. Assistant/guard to communicate [VT9]. Cab displays [VT10].
Operational Blind Spots:	Damaged windscreens generally impaired forward vision – problem exacerbated by poor headlights and caplamp reflections in the windscreen. An area directly in front of and across the loco sufficient to obscure couplings and anyone bent over attending to the couplings. An area to the off-side extending approximately 10m ahead of the loco (restricted by size of windscreen). Large stretches of track were submerged in water which concealed objects which constituted potential derailment risks.
Major Postural Changes:	Driver has to lean to left to see off-side of tunnel. Driver has to lean forward to see couplings.
Visual Environment:	
Illuminance-	For the loco fitted with two white and one red headlight, illumination across the tunnel was 8 lux at 20m. On a similar loco fitted with three white headlights was 10 lux at 20m There was no interior cab illumination. It was not possible to take measurements of mine lighting.
Reflectance-	All workmen wore white hard hats and dark blue overalls. Most of the vehicles encountered at roadway intersections were painted white however some tractors were blue.
Contrast-	Viewed against: At rail stops the sides and roof of the tunnel were whitewashed. Away from the stations, a good standard of stone dusting had been maintained. The ground was dark grey/black and in many places was submerged in

	water.
Visual conditions-	See comments above regarding affects of ground water and windscreen reflections. There were no dust problems.
Classification-	Identification and course tracking
Operators comments-	See below.

Visual Attention Area to the Rear alongside the Train

Visual Targets:	Along the sides of the train to check the safety of passengers alighting and boarding [VT7]. Along the sides of the train to check the security of loads and the rolling stock [VT8]. Assistant/guard - to communicate [VT9].
Operational Blind Spots:	It was impossible for the driver to see to the rear without leaving his seat and leaning through the door. Even then, it was possible to see only along the near-side of the train. It was impossible to see the assistant drivers/guards unless they stood in front of the locos (some 20m away from the cabs where they normally sat)
Major Postural Changes:	Driver has to leave seat and lean out of doorway to see to rear of train.
Visual Environment:	
Illuminance-	Mine lighting was the only source of illumination towards the rear and this was normally only provided at the rail stops/stations. (See assessments of rail stops under static locations for typical lighting levels.)
Reflectance-	See previous table
Contrast-	See previous table
Visual conditions-	See previous table
Classification-	Identification and course tracking
Operators comments-	See below.

Drivers' comments

- Poor track conditions exist in some parts of the mine
- Various information signs not clearly visible, for example, stop signs, crossing signs, etc.
- Defects in windscreens reported – no action taken
- In locos with missing windscreens, dust particles enter hi eye
- Submerged tracks cannot be seen and create derailment potential
- Many lights in shaft area do not operate

Significant factors from other studies of this loco

An examination of other examples of the same type of loco operating at both the same and other mines identified the following additional limitations:

- On some locos, light output diminished to a glimmer when engine ran at idle speed.
- There was no standard arrangement for the lights provided on different locos. In some cases a column of three white lights was provided, in other a column of two white and one red light was provided in no specific configuration.
- Since all lights at both ends of the locos operated when the engine started it was difficult to appreciate the purpose for the provision of red lights on some locos.

- There was no preferred side for boarding and alighting man carriages, For safety purposes it was necessary for the drivers and their assistants to check along both sides of the train before moving off.
- No reliable form of communication was provided between the drivers and their assistants.
- Locos were allowed to operate through areas where the tracks were submerged in water.
- Speedometers were not provided on some locos. Where speedometers were provided, they were not illuminated. To see the instruments drivers had to use their caplamps, which caused reflection problems with the windscreen.
- Almost all windscreens were damaged and impaired visibility; some windscreens had been removed completely.
- Lights on several of the locos were damaged, similarly several of the mine light units were defective.
- No form of lighting provided on the rear carriages or material cars.

Deviations from Procedures

The majority of the above limitations result from deviations and/or a failure by the mines to comply with their own written safety standards.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Passengers and assistants injured in the act of climbing in and out of carriages when train moves off.	Driver has restricted view of passengers on near-side. Driver has restricted view of assistant working on off-side. Lack of effective communications with assistant. Tolerance of informal boarding and alighting arrangements
2. Derailment through failure to identify defective track ahead.	Detection of defects impaired by damaged windscreens, speeding , limited illumination from loco headlights and rails submerged in water.
3. Collision into back of stopped trains.	Limited provision of warning lights on back of trains. Detection affected by damaged windscreens, caplamp reflections and limited illumination from loco headlights. Confusion caused by use of non-standard arrangements of lights.
4. Assistants/Shunters trapped when coupling loco to carriages and material cars.	Line of sight restrictions immediately in front and to the off-side of the loco. Driving control error resulting from need to adopt adverse operating postures.
5. Collision with workmen and obstacles ahead including vehicles at crossings.	Low reflectance and hence poor contrast visibility of workforce due to use of dark blue overalls and some dark coloured vehicles. Detection affected by damaged windscreens, caplamp reflections, and limited illumination from loco headlights.
6. Drivers injured when leaning out of cab.	Limited lines of sight along near-side of loco requires drivers to adopt unsafe working postures.
7. Drivers struck in eye by airborne particles.	Limited protection provided by damaged and missing windscreens.
8. Collisions through over-speeding.	Limited provision of speedometers.

	Speedometers provided not reliably used - drivers switch off caplamps to avoid reflections from windscreen. Speedometers not illuminated

Significant factors associated with the design and operation of 18T engine powered loco.

This design of loco is provided with a single two-man cab at one end wherein the drivers and their assistants are provided with swivelling seats which enable them to always face the direction of travel. Assessments established that most of the limitations associated with the design, operation and environment in which the 25T loco operated are also applicable to this machine. Therefore, in order to avoid repeating much of the above assessment, only the important differences are detailed below.

- With the provision of a two-man cab, communication between the drivers and guards is more effective and the risk of injuring people by moving off while they are still climbing on or off the train, is considerably reduced.
- Forward sight lines when travelling with the engine leading are considerably worse that on the 25T unit, particularly towards the off-side which is almost completely obscured by the engine housing. To compensate, the drivers rely on their assistants to 'spot' for them. Their forward view is also restricted by the small 450mm diameter windows provided. Looking straight ahead, the drivers are unable to see the rail tracks for a distance of 10m. Furthermore, they are unable to see the off-side wall of the tunnel for a distance of 30m.
- Forward sight lines when travelling with the engine trailing are marginally worse than on the 25T unit.
- Given the above sight line limitations, there is an increased risk of trapping people engaged in coupling the loco to rolling stock and colliding with people setting off.
- One particular loco assessed was provided with a row of two white headlights at each end. The lights were mounted near the top of the loco and were 100m diameter, 12V, 50W, Wagner units. Illumination levels measured at 20m were 4 lux ,and at 10m, 10 lux.
- As in the case of the 25T unit, light arrangements varied from loco to loco with some painted red and some defective. The resulting lack of illumination and the potential for confusion increased collision risk potential.

STATIC LOCATIONS

Static locations are areas on the mines where the provision of permanent fixed lighting installations are likely to be the most practical. This section of the appendix addresses a broad sample of such locations and considers the visual environment of workmen engaged in activities in these areas. The static locations considered included inclined shafts and shaft stations, shaft bottom areas, junctions, transfer points, workshops, haulage routes and travelways, electrical sub-stations and fuel stores.

Each assessment contains:

- Description of the operations undertaken.
- Key dimensions.
- Sources of illumination.
- Assessment of the visual environment
- Significant potential hazards associated with the visual limitations identified.

In addition, where it was possible to observe activities being undertaken, the assessments also contain:

- Task descriptions.
- Identification and assessment of visual targets.
- Critical visual attention areas
- Assessment of the visual environment for each visual attention area.

Inclined Shaft and Shaft Station

The following assessments were undertaken on an inclined shaft and the station at the bottom of the incline. The inclined shaft featured a rope haulage system for the movement of supplies, and a chairlift system and steps for men to use. (Assessments of the areas at the bottom of vertical shafts are dealt with in the next section).

Inclined Shaft - incorporating chairlift

Operation:	Walking down inclined shaft.
Key Dimensions:	See diagram below: The inclined shaft ran a distance of 900m from the entrance on the surface to the shaft station. The shaft was 5m wide x 2,5m high. Supplies were taken down the shaft using a bogie which ran almost centrally within the shaft on rails and which was operated by a rope haulage system. To the right of the haulage system (looking down the shaft) was a chair-lift and a set of steps for pedestrians to use when the chair-lift was not in use. Overall width of the staircase was 600mm. Individual step sizes varied but generally they were about 250mm x 250mm deep. The chairs hung centrally over the stairway. The stairs were regularly used to enter the mine when supplies were being transported.
Sources of Illumination:	Twin 1,8 m fluorescent 75W tubes spaced 6m apart fastened to walls 2,0m above the ground (0,5 from roof) on opposite side of shaft to steps
Visual Environment:	Walls and roof were old peeling whitewash with low reflective properties. The original white paint had worn off the steps. Chairs (original dark blue paint worn away in places) did not contrast with background.
Illuminance	Measurements taken on the steps: 2,5 lux adjacent to light unit 1 lux between light units 1 lux adjacent to a defective light unit About one in four of the light units was defective
Visual Conditions	Poor. Given the location of the lights (at the opposite side of the shaft), the proliferation of defective units creates areas of deep shadow, the length and condition of the stairway, absence of handrails and obstructions caused by chairs adversely impacts on visual conditions

Blind Spots None

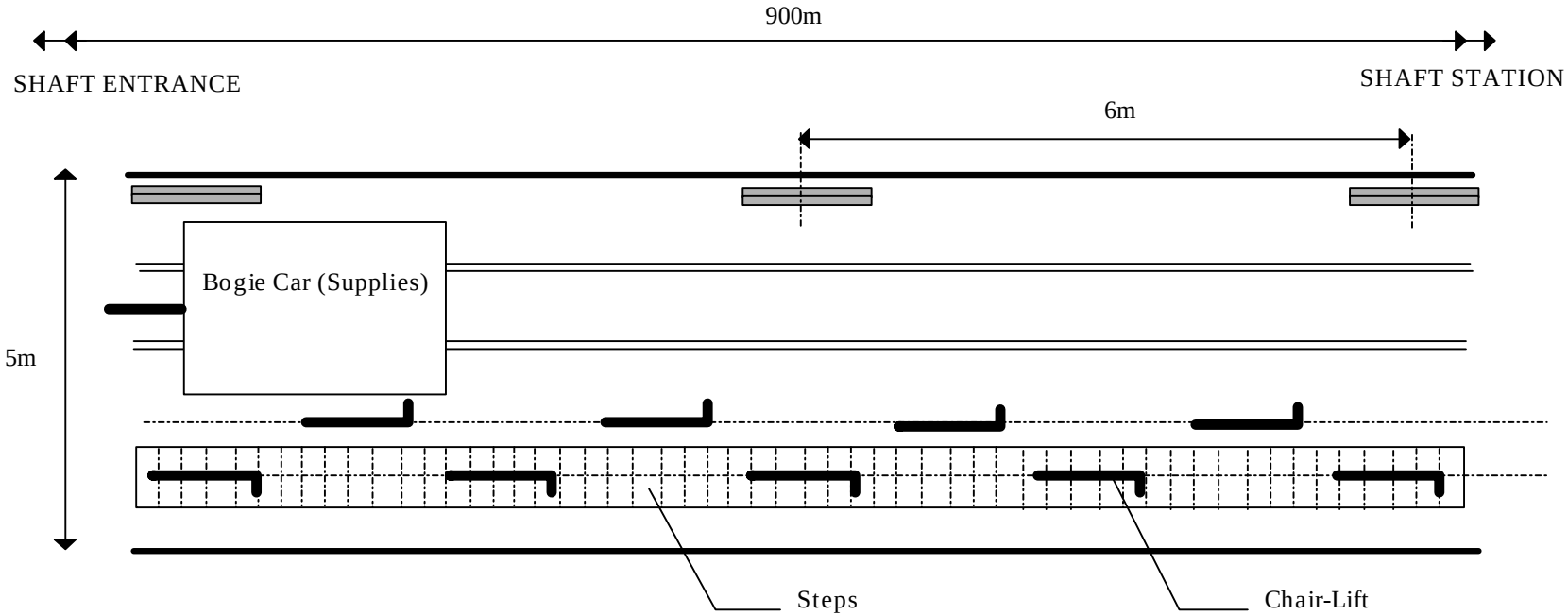
General conditions

Steps were concrete and generally well swept ,although there were some loose stones.

Step size varied appreciably and the steps were wet in places with water running across them. There were no handrails provided.

Chairs suspended every 3 to 4 m in the centre of the stairway presented an obstruction.

Pipe ranges and other equipment mounted on shaft wall next to stairway.



Inclined Shaft Incorporating Chairlift

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Slip/trip/fall down stairway	Limited illumination levels Defective light units Limited visibility of steps and floor conditions. Poor reflectance from walls and roof Varying step sizes No handrails provided
2. Walking into suspended chairs and equipment mounted on the ribside of the shaft next to the stairway.	Poor reflectance and hence visibility of chairs due to dark colouring

Shaft Station at bottom of inclined shaft

Operation: Boarding/Alighting chair lift, and loading operations.

Key Dimensions: See diagram below:

Both operations took place in the shaft station i.e. the point of transition between the inclined shaft and the main arterial roadway into the mine. The section size of the inclined shaft and roadway was 5m wide x 2,5m high. A haulage system (examined in the following section) terminated in a gully **A** located alongside the chairlift alighting and boarding point **B** & **C**. The gully was flooded with water. A range of vehicles were used in the loading area including LHDs, tractors and trailers, personnel carriers etc. Both manual and mechanised methods of loading where employed. A steel mesh fence **D** prevented workmen entering the mine on the chairlift from direct contract with any vehicles in the loading area.

Sources of Illumination: See diagram below:

Twin 1,8 m 75W fluorescent tubes suspended centrally above the end of the haulage run 0,5m from roof.

Twin 1,2 m 40W fluorescent tubes mounted 3m inbye above the boarding/alighting station 0,5m from roof.

Twin 1,8 m 75W fluorescent tubes suspended diagonally across the centre of the roadway 10m inbye.

Visual Environment: Walls and roof were old peeling white wash with low reflective properties.

Floor was firm damp/wet coal.

Light units were coated in a layer of dust, which significantly impaired output levels.

Most of the vehicles entering the loading area were painted white but some tractors were dark blue.

Chairs (original dark blue paint worn away in places) did not contrast with background.

Illuminance Measurements taken 1m above the ground:

1 lux at the chairlift alighting point

23 lux measured directly above the supply bogie at termination of the haulage i.e. point **A**.

23 lux at the chairlift boarding points **B** & **C**

13 lux in the centre of the loading area i.e. 5m inbye from point **A**

5 lux at the sides of the loading area.

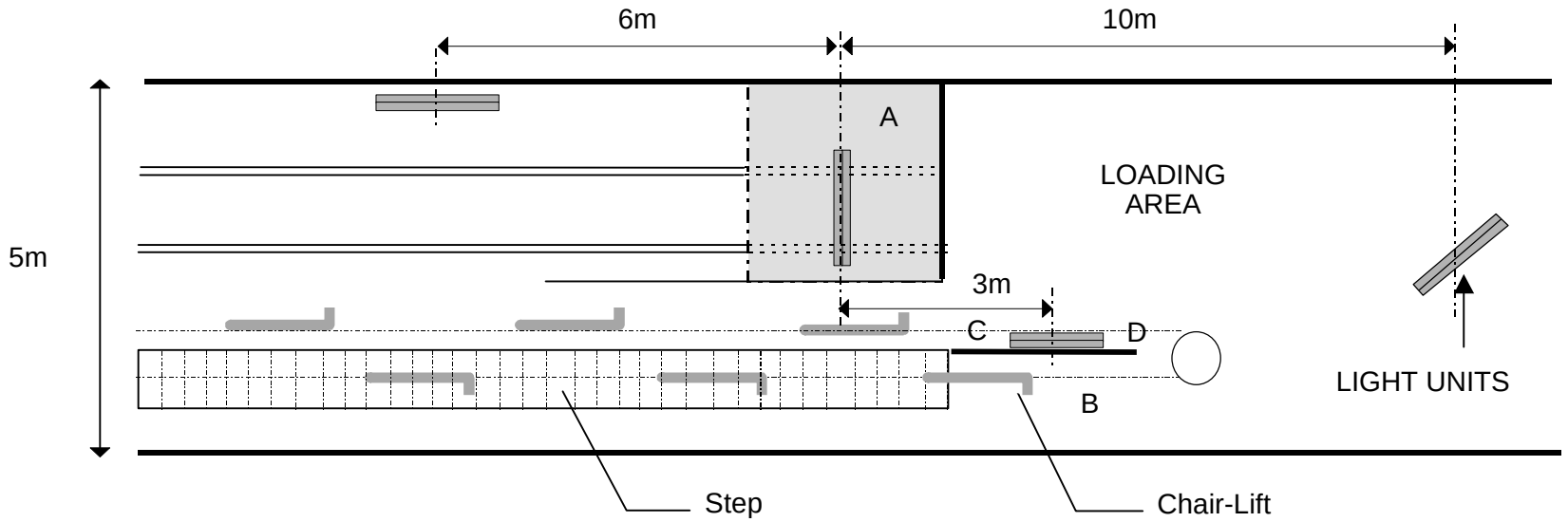
27 lux directly under the light unit 10m inbye from point **A.**

Visual Conditions Poor: the chairlift alighting point was in deep shadow; elsewhere lighting levels were low given the potentially hazardous nature of the work undertaken.

Blind Spots Several blind spots when handling supplies manually and using mechanical appliances at the sides of the loading area.
Most of the vehicles entering the loading area had restricted sight lines.

General conditions The floor was generally free from obstructions, although in places it was extremely slippery from water running

down the inclined shaft. Supplies removed from the haulage were frequently stored at the sides of the loading area.



Shaft Station at Bottom of Inclined Shaft

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Slip/trip/fall whilst alighting chairlift	Limited illumination levels restricts visibility of wet slippery ground conditions. Poor reflectance from walls and roof.
Manual handling injuries	Limited illumination levels restricts visibility of critical points during handling operations. Poor reflectance from walls and roof.
Struck by vehicle	Vehicle horns/whistles not always provided and not reliably used. Some vehicle lights defective, some dim when engine revs drop. Colouring on some vehicles does not contrast with background

	Restricted sight lines on most vehicles entering the loading area.

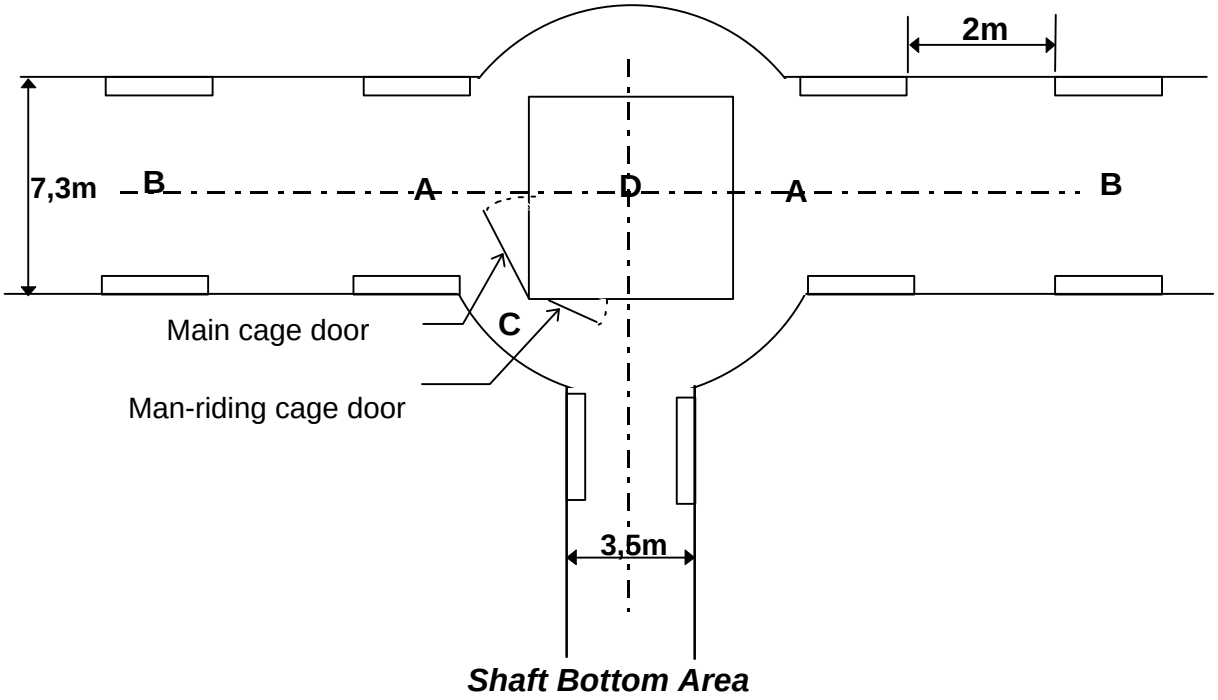
Design limitations on the vehicles entering the loading area, which influence the above hazards, are dealt with the individual assessments of these vehicles.

Shaft Bottom Areas

The following two assessments were undertaken in areas at the bottom of vertical shafts.

Shaft Bottom Area 1.

Operation:	Use of man-riding cage/lift.
Key Dimensions:	See diagram below: Roadway section extending either side of shaft is 7,3m wide x 3,3m high. Pedestrian walkway round shaft is 1m wide. Personnel use the man-riding lift - lift attendant rides in top deck Cage is used for transporting vehicles and supplies.
Sources of Illumination:	Twin 1,2 m fluorescent 75W tubes spaced as shown in diagram. Lights are fastened to walls 2,5m above the ground.
Visual Environment:	Walls are painted dark blue to a height of 2m. Above 2m the walls and roof are white washed with good reflective qualities. The cage and supporting structures were painted orange. Ground was dry concrete well swept and there were no loose obstacles.
Illuminance	150 lux in centre of roadway 1m in front of cage doors at each side of shaft (points A on diagram). 120 lux in centre of roadway 4m from front of cage at each side of shaft (points B on diagram). 50 lux measured directly in front of man-riding lift (point C on diagram). Estimated 100 lux in cage (point D on diagram).
Visual Conditions	Good. No sources of glare, dust, deep shadows or high air velocities.
Blind Spots	Operator opening cage door adjacent to man-riding lift unable to see men queuing, entering or leaving bottom deck of lift. Lift operator has restricted vision of men queuing, entering, leaving bottom deck of lift.



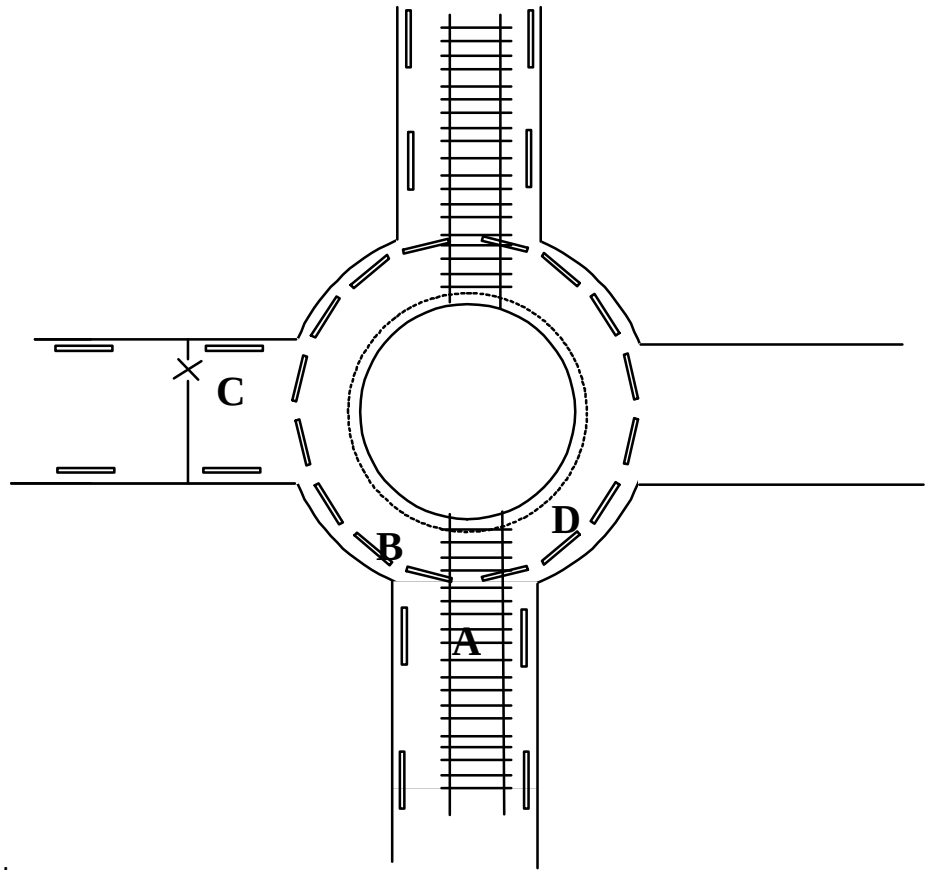
Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Men stuck/trapped by opening cage door	Limited sight lines
Trapped by prematurely closing lift door	Limited sight lines

Shaft Bottom Area 2.

Operation:	Use of man-riding cage and material lift.
Key Dimensions:	See diagram below. The pedestrian and vehicle roadways approaching the shaft are 6m wide x 4,5 m high. Pedestrian walkway round the shaft is 2m wide. The shaft is surrounded by a screen. Personnel use the separate man-riding lift, which can only be accessed from the pedestrian roadway. A turnstile and screen prevents pedestrians from walking into the vehicle roadway. The operator of the man-riding lift rides in the lift with personnel. The main cage is used for transporting equipment and materials. Both lift cages are well illuminated.
Sources of Illumination:	See diagram Twin 2,4 m x 75 W tubes spaced 1,5 m apart. The lights are fastened to the walls suspended 3,5 to 4,0 m above the ground round the “walkway”. Twin 2,4 m x 75 W tubes suspended longitudinally 4,0 m apart 0,5m from the roof in the roadway.
Visual Environment:	The roof and sides of the vehicle roadway and shaft are whitewashed and dry. The floor is grey concrete. A set of rails is installed in the middle of the roadway extending up to the shaft for handling rolling stock e.g. locos, material cars, mancarriages, etc. The floors were level, dry and clean with no loose obstacles. A similar visual environment was provided on the pedestrian roadway. The floors were level, dry and clean with no loose obstacles. Although a 200mm step constitutes a potential tripping hazard, lighting conditions provided by the three additional fluorescent light fittings was good. The screens around shafts as well as screen doors were painted yellow with black lines diagonally across.
Illuminance	160 lux in centre of roadway to material cage (point A on diagram). 160 lux outside the material cage door (point B on diagram). 160 lux at the turnstiles and screen entering the man-riding cage area (point C on diagram). 72 lux at an electrical box (point D on diagram).
Visual Conditions	The lights were kept clean and visual conditions were good. There were no sources of glare or deep shadows. Air speeds were low and there was no air borne dust.
Blind Spots	None



Shaft Bottom Area 2.

Potential Hazards

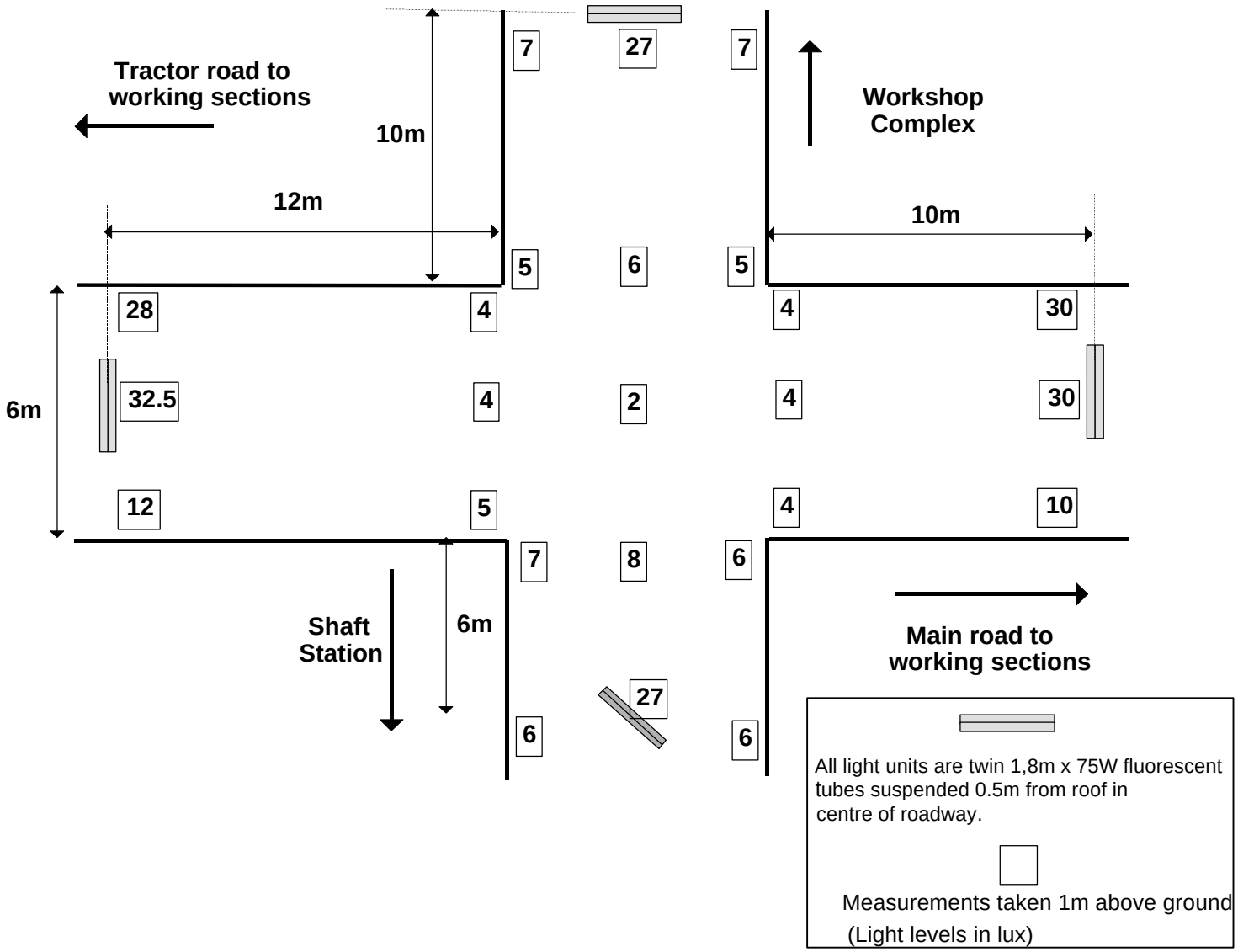
No visual limitations were identified that were likely to contribute to the risks arising from any of the inherent hazards that existed in the area.

Junctions

Assessment details for two junctions between main haulage routes are detailed below. Traffic using the junctions included pedestrians and a range of mobile machinery.

Junction 1.

Operation:	Walking in and out of the mine
Key Dimensions:	The junction was between a main arterial road entering the mine from the shaft station, and turnings to the right and left to various production sections. All roadways were 6m wide x 2,5m high. The roadways constituted the main walkways for men entering the mine. In addition to people, a number of vehicles were seen being driven along the roadways including LHDs, tractors and graders.
Sources of Illumination:	Caplamps only at the junction Twin 1,8 m 75W fluorescent tubes suspended 0,5m from the roof were provided in the roadways up to the junction as detailed in the diagram below.
Visual Environment:	Old stone dust on walls and roof with low reflective properties. Floor was firm dry coal. Light units were coated in a thick layer of dust, which significantly impaired output levels. Most of the vehicles travelling the area were white painted but some tractors were dark blue. Many vehicles had defective lights All workmen wore white hard hat, blue overalls and reflective jacket.
Illuminance	lux levels were measured at a number of points and are indicated on the diagram.
Visual Conditions	Variable: Conditions in the roadways was generally good with no sources of glare, or high air velocities. Areas at the side of the roads were however in deep shadow. The junction was in deep shadow creating significant accident potential.
Blind Spots	Blind spots at each turn when walking through the junction. Most of the vehicles using the roadways had restricted sight lines.
General conditions	Junction floor had been churned up by the wheels of heavy vehicles. There were ridges of loose material and loose stones. Floor conditions in the roadways was generally firm and free from obstructions.


Tractor road to working sections
10m
12m
6m
Shaft Station
6m
Workshop Complex
10m
Main road to working sections
7
27
5
6
28
4
32.5
2
12
8
All light units are twin 1,8m x 75W fluorescent tubes suspended 0.5m from roof in centre of roadway.
Measurements taken 1m above ground
(Light levels in lux)

Junction 1.

Potential Hazards

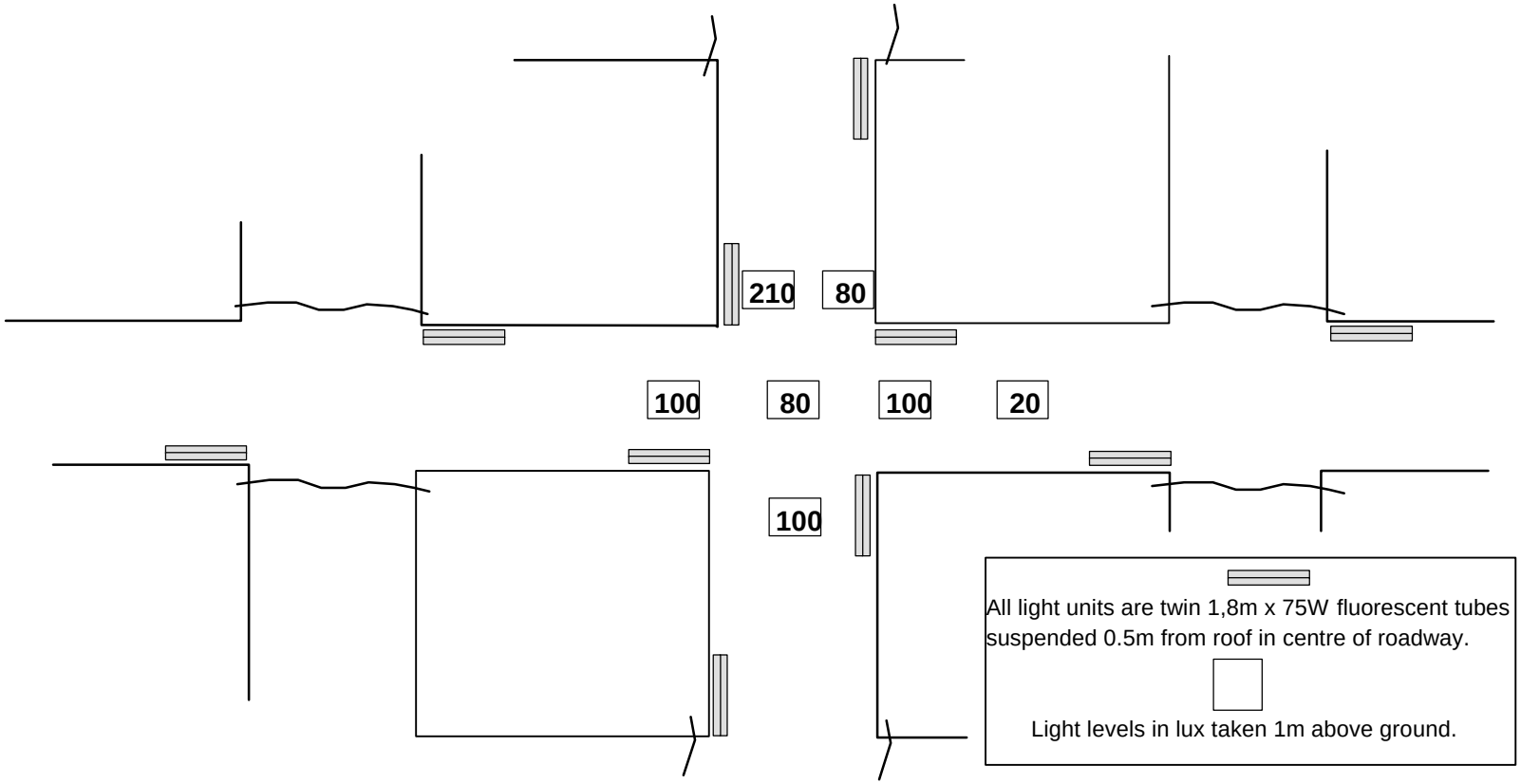
The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Slip/trip/fall walking through junction	Limited illumination levels restricts visibility of uneven ground and stumbling hazards. Failure to clean lights impairs potential light output Poor reflectance from walls and roof.
Struck by vehicle (from behind or emerging suddenly from turns).	Vehicle horns/whistles not always provided and not reliably used. Some vehicle lights defective, some dim when engine revs drop. Colouring on some vehicles does not contrast with background Restricted sight lines on most vehicles entering the loading area.

Design limitations on the vehicles entering the loading area, which influence the above hazard, are dealt with in the individual assessments of these vehicles.

Junction 2.

Operation:	Walking in and out of the mine
Key Dimensions:	The junction was between two main roadways in a mine. All roadways were 6m wide x 2,5m high. The roadways constituted the main walkways for men entering the mine. In addition to people, a number of vehicles were seen being driven along the roadways including LHDs, tractors, LDVs, MPVs and graders.
Sources of Illumination:	Twin 1,8 m 75W fluorescent tubes suspended 0,5m from the roof were provided in the roadways up to the junction as detailed in the diagram below. Note that two rows of luminaries were provided, one on each side of the roadways, spaced such that they were on alternating sides and oriented in line with the roadway.
Visual Environment:	Fresh stone dust on walls and roof with good reflective properties. Floor was firm dry coal. Light units had recently been cleaned. Most of the vehicles travelling the area were painted white but some tractors were dark blue. Many vehicles had defective lights All workmen wore white hard hat, blue overalls and reflective jacket.
Illuminance	lux levels were measured at a number of points, and are indicated on the diagram.
Visual Conditions	Variable: Conditions in the roadways was generally good with no sources of glare, or high air velocities.
Blind Spots	Blind spots at each turn when walking through the junction. Most of the vehicles using the roadways had restricted sight lines.
General conditions	Junction floor had recently been graded and was therefore level. There was some residual material floor scrapings at the sides. Prior to grading the ground had been churned up by the wheels of heavy vehicles which left ridges of loose material and loose stones. Floor conditions in the roadways was generally firm and free from obstructions.



Junction 2.

Potential Hazards

With the levels of illumination combined with the high standards of maintenance and housekeeping in the area, no visual limitations were identified that were likely to contribute to the risks arising from any of the inherent hazards that existed.

Note: the junction assessed above was a new arrangement that had been introduced by the mine on a trial basis to improve lighting standards in roadways. Measurements indicated that the arrangement provided a good even distribution of light at junctions regardless of travel direction and reduced the areas of dark shadow associated with other lighting arrangements provided at junctions.

Transfer Points

Assessment details are given below for two material transfer points. The first assessment includes a detailed task analysis of spillage clearance activities performed by the transfer point attendant, while the second assessment examines a different transfer point in more general terms.

Transfer Point 1.

Operation: A plan view of the transfer point is given below. Mineral extracted from a number of working sections was taken by overhead conveyor through a belt road to this point where it was transferred via a chute onto a main conveyor. Some spillage and occasional blockages occurred and an attendant was employed to deal with these problems. The attendant was observed shovelling up spillage on both sides of the main belt conveyor.

Key Dimensions: Both the belt roads were 2,5m high x 6m wide. The conveyor system ran along one side of the belt road although on the tight side there was a walkway of at least 1m wide in which to work. Steel steps and a narrow elevated platform provided the means of crossing the conveyor.

Sources of Illumination: Single 100W light bulbs were suspended 0,5m from the roof every 16m along the length of the roadway. The lights were above the narrow walkway on the tight side of the conveyor.

Three sets of twin 1,8 m 75W fluorescent tubes were suspended 0,5m from the roof in the positions shown on the diagram.

Hierarchical Task Description for attendant

Task Elements	Visual Targets	Hazard No.
Shovel spillage from walkway side of belt road onto belt	VT1 Spillage from belt VT2 Conveyor belt VT3 Conveyor framework	2
Travel to opposite side of belt		
Walk along walkway to platform	VT4 Walkway	1
Cross over platform	VT5 Steps, handrail and floor of platform	3
Walk along walkway on tight side to spillage	VT4	1
Shovel spillage from walkway on tight side of belt road onto belt	VT1, VT2, VT3	2
Return to previous side of belt (repetition of above).	VT4, VT5	1, 3

The visual targets identified above were grouped into the following three visual attention areas**:**

Spillage areas

Visual Targets:	Spillage from belt on floor [VT1] Conveyor belt [VT2]

	Conveyor rollers and framework [VT3]
Operational Blind Spots:	None
Major Postural Changes:	None having visibility/lighting implications, but shovelling was undertaken in stooped posture
Visual Environment:	
Visual angle-	Spillage occurs on either side of the belt for a distance of about 2m from the discharge chute Approximately one square metre of belt 1m from attendant.
Illuminance-	Measurements taken within the spillage area 0,5m off the ground are given on the diagram.
Reflectance-	Accumulations of spillage at the side of the belt are mainly damp coal. Conveyor belt is black, conveyor structure is painted a dark colour.
Contrast-	Very low: spillage, belt and conveyor structure are similar colour to ground
Visual conditions-	Generally good, however, there was a continual presence of airborne dust from conveyor and a settling of dust on lights restricted output levels.
Classification-	Detection/course tracking
Operators comments-	Occasionally stumble over items on floor. Often strikes shoulder and elbow on conveyor framework and rollers respectively.

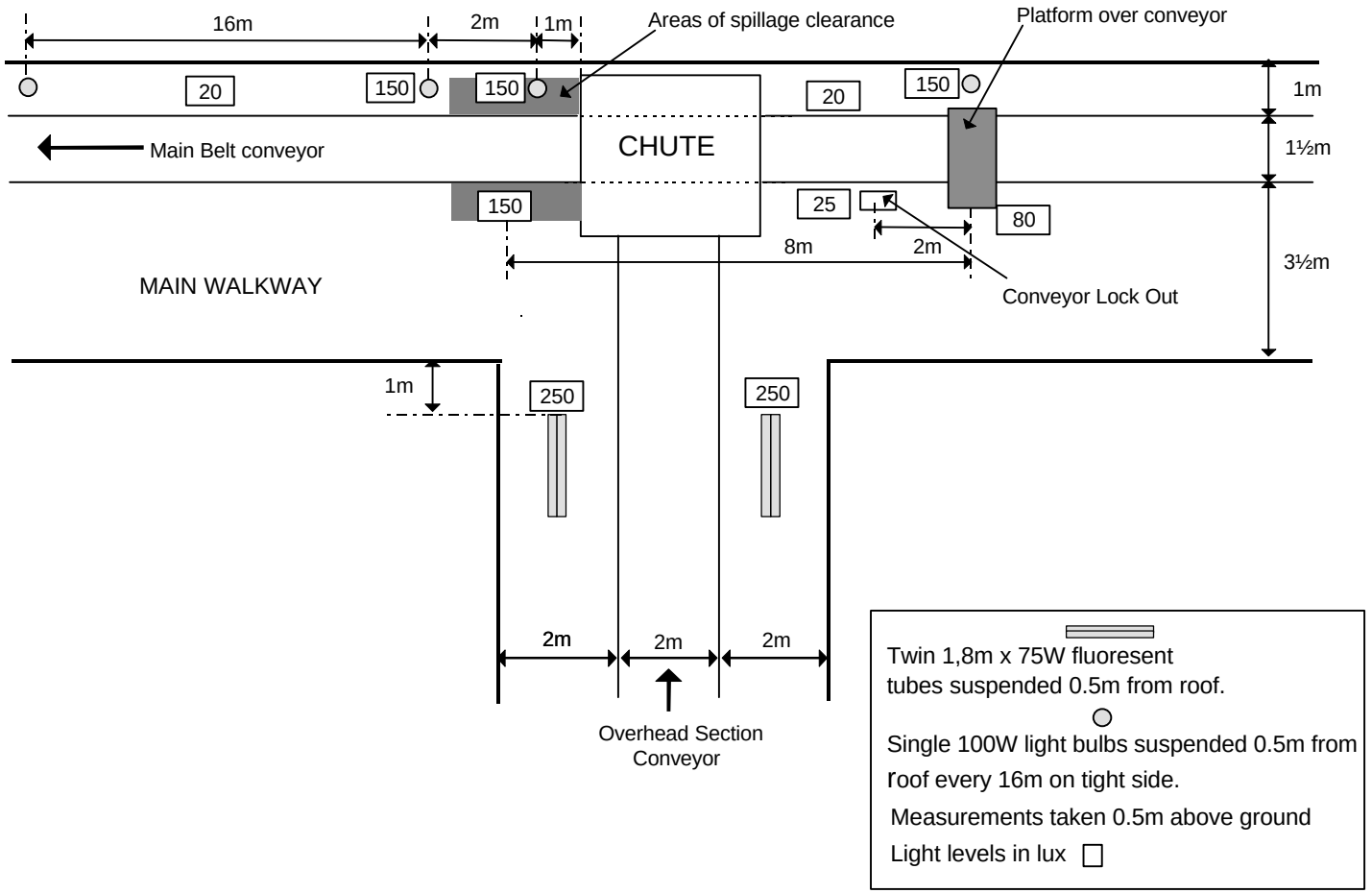
Walkways on either side of conveyor

Visual Targets:	Walkway [VT4]
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Visual angle-	Trip hazards (approx. 100mm at 2,5m)
Illuminance-	Illumination levels varied - see measurements on diagram.
Reflectance-	Side walls dry with old coating of stonedust with low reflective properties. Floor dry with compacted coal dust with scattering of loose cobbles.
Contrast-	Very low, obstacles same colour as walkway.
Visual conditions-	Generally good, however, there was a continual presence of airborne dust from conveyor and a settling of dust on lights restricted output levels.
Classification-	Detection
Operators comments-	Occasionally stumble over items on floor.

Elevated platform

Visual Targets:	Steps, handrail and floor of platform [VT5]
Operational Blind Spots:	None
Major Postural Changes:	None.
Visual Environment:	
Visual angle	Platform structure at a range closing to 0,5m
Illuminance-	See values marked on diagram

Reflectance-	Low, platform was painted a dark colour.
Contrast-	Very low, steps, platform and handrails were same colour as walkway
Visual conditions-	Generally good, however, there was a continual presence of airborne dust from conveyor and a settling of dust on lights restricted output levels.
Classification-	Identification/Course tracking
Operators comments-	None



Material Transfer Point 1.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1 Slip/trip/fall over obstacles on floor.	Poor general housekeeping in area – trip obstacles, failure to clean lights. Airborne dust and low contrast between tripping obstacles and ground.
2 Strikes shoulder/elbow on conveyor rollers and framework	Colouring of conveyor framework does not contrast with background.
3 Slip/trip/fall negotiating platform	Platform colouring does not contrast with background.

Transfer Point 2.

Operation: The operation and general layout of the transfer point was similar to Transfer Point 1. In that coal from a number of production areas was transferred onto a main belt by an overhead section belt conveyor. A diagram of the transfer point is given below.

Key Dimensions: The main belt roadway was 7,0m wide x 1,8 m high. To facilitate the overhead section belt, the roadway at the transfer point had been raised to 4,0m. The main belt ran centrally along the centre of the roadway. Steel steps and a narrow elevated platform provided the means of crossing the conveyor. Spillage was monitored remotely by CCTV camera thereby obviating the need for the permanent presence of an attendant.

Sources of Illumination: Twin 1,8m x 65W fluorescent lights spaced 3m apart and mounted longitudinally to the roof of the travelways 0,8m from the ribsides.

Two additional lights similar to the above were spaced 3m apart 2,5m off the ground near the chute discharge to provide illumination for the CCTV camera.

One similar light was fitted across the belt at the bridge over the belt behind the transfer chute (see diagram).

Where the roof height had been increased to 4,0m the lights were mounted 2,5m off the floor.

Visual Environment: Water sprays at the point of discharge provided an effective means of dust control.

The walls and roof had been freshly stone dusted and provided high reflectance levels. The floor was covered in dry fine coal dust.

The conveyor system and platform were painted black which provided a contrast with the walls but not the floor, belt or the general ambience.

Travelways were kept in good condition and there were no tripping hazards

Illuminance Illumination levels measured in the travelways alongside each belt system averaged 150 lux (measurements taken at ground level.

Measurements taken at point **A** on the diagram where a workman was observed clearing spillage were typically 25 lux (caplamp switched off).

160 lux was recorded at the chute discharge (point **B** on diagram). This is the area subjected to televised monitoring

80 lux was measured at the screens covering the belt drive rollers where people would work when carrying out repairs (point **C** on the diagram).

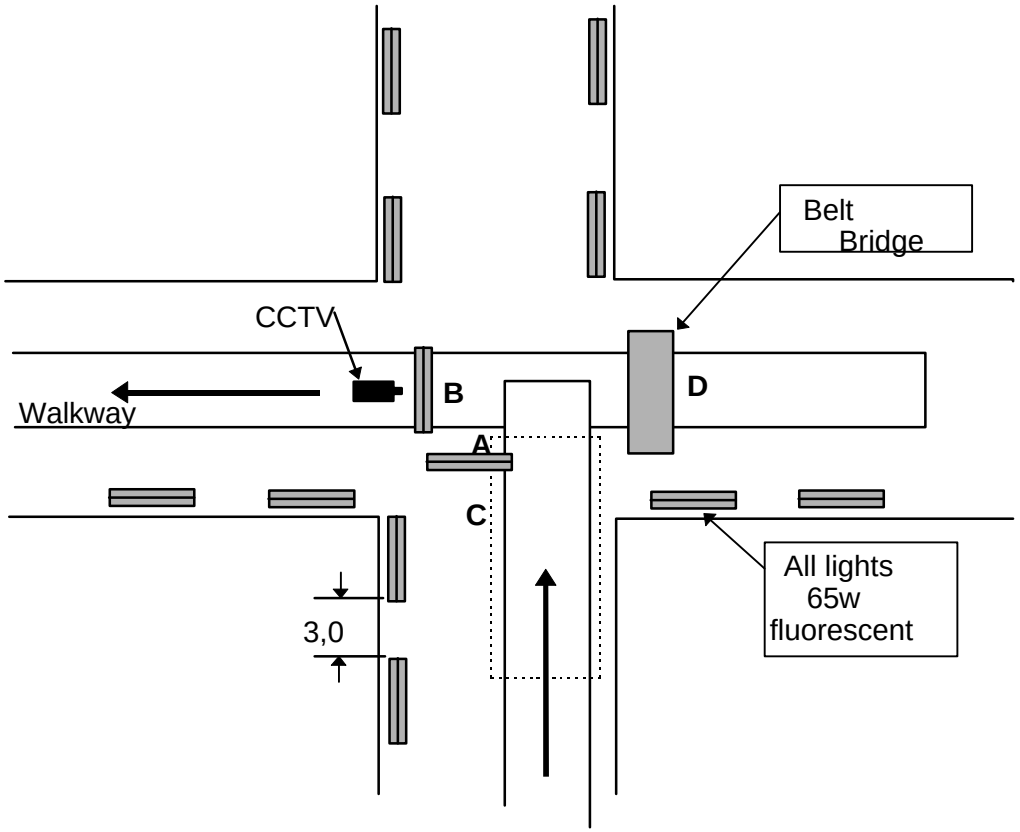
160 lux was measured on the floor of the platform over the conveyor (point **D** on diagram).

Lighting levels on the opposite side of the opposite side of the conveyor to the travelway were typically 25 lux at ground level.

Visual Conditions Good, There were no sources of glare or blind spots, and airborne dust was sufficiently well controlled to have no significant impact on the visual environment.

At the point of discharge, the section belt passed above the level of the lights, however, no visual limitations were

identified.
The walkway over the belt was well illuminated (160 lux). All lights in the area were working.



Transfer Point 2.

Potential Hazards

No visual limitations were identified that were likely to contribute to the risks arising from any of the inherent hazards that existed in the area examined.

Workshops

The project examined a range of workshops in different mines. Assessment details relating to three of the workshops examined are given below. These examinations cover:

1. A diesel workshop in which routine maintenance and breakdown repairs were undertaken on a range of diesel powered vehicles including LHDs, tractors, LDVs, graders and other personnel carriers.
2. A workshop in which maintenance and repairs were undertaken on the mine's fleet of personnel carriers.
3. A boilershop within which lightweight fabrication and machining operations were undertaken.

Following these assessments a list of significant factors resulting from examinations of other workshops has been included.

Workshop 1. - Diesel workshop

Key Dimensions: An area of old board and pillar working had been transformed into the diesel workshops. The individual galleries had been created from a series of intersecting headings into which main water and power supplies had been extended. The floors had been concreted and the walls bricked. In cross-section, the galleries were 6m wide x 2,5m high. There were no pits to facilitate work beneath the vehicles; To undertake this work fitters lay on their backs under the vehicles. Sometimes the vehicles were raised on timbers to provide more clearance.

Lighting levels were assessed in three galleries where a tractor, an LHD and a grader were being attended to.

Sources of Illumination: Twin 1,8 m fluorescent 75W tubes spaced 3-4m apart, suspended 0,5m from the roof were provided at each side of each gallery.

Visual Environment: Walls were painted dark green to a height of 1,0m; above 1,0m they were white-washed..

The ground was concrete stained almost black by the spillage of machine oil.

The roof was coal.

Illuminance Measurements taken on the floor at various points round each of the vehicles (about 1,0m from the vehicles) ranged from 50 lux to 150 lux, depending on whether the measurements were taken adjacent to or between light units.

Measurements taken at various points along the exterior surface of the vehicles ranged from 30 lux to 100 lux.

Measurements taken at various points underneath the tractor and LHD ranged from 1 lux to 5 lux.

Lighting levels inside the engine compartments of the three vehicles ranged from zero to 5 lux.

Visual Conditions Visual conditions varied considerably. Away from the vehicles no visually related hazards were identified, however, most operations carried out underneath or within the vehicles were cast in deep shadow. Light from the fluorescent tubes was cut off by the presence of the fitters, the size of the access openings and the internal layout of the vehicles. Furthermore, postural demands prevented fitters from making effective use of their caplamps.

Blind Spots There were many blind spots due to the size of the various access openings and the location of the various

General conditions	components that required routine servicing. Maintenance frequently had to be undertaken on hot engines which, coupled with restricted sight lines and poor levels of on-board illumination, was regarded by the fitters as their main hazard concern. The floor was generally free from obstructions although in places it was extremely slippery from the presence of oil and grease.

Deviations from procedures:

When working inside vehicle enclosures, some fitters:

- remove their caplamps (and self rescue units) and use them as portable light units
- remove their hard hats to enable them to place their heads inside the enclosures to see more effectively.

Potential hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Hands injured through being: • in contact with hot, sharp objects, and • trapped or struck when using tools [Level of tactile precision required to complete many of the tasks precludes the use of heavy gloves]	Restricted visual access to components that require to be worked on. Limited illumination levels on components within vehicle enclosures Restricted workplace conditions
2. Components and substances falling on men working underneath vehicles.	Poor reflectance from walls. Limited illumination levels to components beneath vehicles. Limited visibility stemming from combination of above and restricted workspace conditions.
3. Head injuries caused by working without hard hat	Combination of restrictions detailed above created the tendency for some workmen to remove their hard hats to overcome visual access restrictions
4. Caught without caplamp and self rescue unit in the event of an emergency	Combination of restrictions detailed above created the temptation for some workmen to remove their caplamps and use them as portable light units.

Workshop 2. - Personnel Carriers

Key Dimensions:

An area of old board and pillar working had been transformed into the workshop and into which mains water and power supplies had been extended. The floors had been concreted and the walls bricked. The workshop was 15m long x 5m wide x 3,3m high. There were no pits to facilitate work beneath the vehicles. To undertake this work fitters lay on their backs under the vehicles. Sometimes the vehicles were raised on timbers to provide more clearance.

At the time of the assessment a vehicle was chocked up to enable replacement of its left front wheel-bearing.

Sources of Illumination:

Twin 1.5 m fluorescent 65W tubes spaced 3m apart, suspended 0,5m from the roof laterally across and in the centre of the workshop.

Visual Environment:

The walls were painted black to a height of 1,0m; above 1,0m they were white-washed.

The ground was concrete stained almost black.

The roof was coal.

Illuminance

The vehicle was parked almost centrally in the garage. Measurements taken on the floor at various points about 0,5m from the vehicles ranged from 50 lux to 200 lux depending on whether the measurements were taken adjacent to and in direct line of the lights, between light units or concealed from the lights.

Measurements taken at various points along the exterior surface of the vehicles ranged from 30 to 250 lux.

Measurements taken at various points underneath the vehicle ranged from 1 lux to 5 lux.

Visual Conditions

Visual conditions varied considerably. Away from the vehicles no visually related hazards were identified, except for the presence of grease on the floor, however, most operations were carried out either underneath the vehicles or under the bonnets and were cast in deep shadow. Light from the fluorescent tubes directly overhead was cut off by raised bonnets, the vehicle chassis and by the presence of the fitters. Furthermore, the postures that the fitters frequently had to adopt prevented them from using their caplamps.
White-washed walls had been darkened in places by exhaust emissions and generally had low reflective properties.

Blind Spots

There were many blind spots and areas of deep shadow.

General conditions

Maintenance frequently had to be undertaken on hot engines which, coupled with restricted sight lines, restricted workspace and poor levels of illumination, was regarded by the fitters as their main hazard concern.

The floor was generally free from obstructions, although in places it was extremely slippery from the presence of oil and grease which could not be distinguished due to lack of contrast with the blackened floor.

Deviations from procedures:

When working inside vehicle enclosures, some fitters:

- remove their caplamps (and self rescue units) and use them as portable light units

- remove their hard hats to enable them to place their heads inside the enclosures to see more effectively.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Hands injured through being: • in contact with hot, sharp objects, and • trapped or struck when using tools [Level of tactile precision required to complete many of the tasks precludes the use of heavy gloves]	Restricted visual access to components that require to be worked on. Limited illumination levels on components within vehicle enclosures or under vehicles Restricted workspace conditions
2. Components and substances falling on men working underneath vehicles.	Poor reflectance from walls. Limited illumination levels to components beneath vehicles. Limited visibility stemming from combination of above and restricted workspace conditions.
3. Head injuries caused by working without hard hat	Combination of restrictions detailed above predisposed a tendency for workmen to remove their hard hats their hard hats to overcome visual access restrictions.
4. Caught without caplamp and self rescue unit in the event of an emergency	Combination of restrictions detailed above predisposed a tendency for workmen to remove their caplamps and use them as portable light units

The foreman fitter considered that the fixed lighting in vehicle workshops should be located around the periphery of the workshop. With such an arrangement there was a better chance of at least some of the light being transmitted under the vehicles and inside enclosures.

Workshop 3. - Boilershop

Key Dimensions: The workshop was located in an old heading that had been transformed into a workshop through the provision of mains water and power supplies, a concrete floor and brick walls, etc. In cross-section the workshop was 6,0m wide x 2,5m high. Located within the workshop were a number of workbenches, a series of lightweight machine tools (hand grinders, pedestal drills, small lathe and shaper, mechanical saw, guillotine, etc.) and a welding table. The welding table was located in the centre of the workshop behind screens. All the remaining equipment was located against the walls round the periphery of the shop.

Sources of Illumination: Twin 1,8 m fluorescent 75W tubes were located to the wall 0,5m from the roof directly behind each workplace.
Two similar light units were suspended 0,5m from the roof directly above the welding table.

Visual Environment: Walls were painted dark green to a height of 1,0m; above 1,0m they were white-washed.
The ground was grey concrete in good condition.
The roof was coal.

Illuminance Measurements taken on the worktable of the different machine tools and on the surface of the workbenches, ranged from a minimum of 380 lux to a maximum of 600 lux. An average reading on the surface of the welding table was 500 lux.

Visual Conditions Visual conditions were extremely good. Lighting levels throughout the workshop were high and there were no areas of shadow. Each workplace was very effectively illuminated and there were no glare problems. The considerable output provided by the number of light units in the workshop more than compensated for any limitations in the poor reflective properties of the green painted lower half of the walls.

Blind Spots There were no blind spots.

General conditions The whole workshop was clean, neat and tidy and there were no tripping hazards on the floor.

No visual limitations were identified that were likely to contribution the risks arising from any of the inherent hazards that existed in the workshop.

Significant factors resulting from examinations of other workshops

Initiatives undertaken at one mine to improve illumination standards in workshops resulted in the fluorescent light fitting being mounted vertically to the walls rather than to the roof. A comparison between the roof mounted lighting arrangements featured in the above assessments and the vertical wall mounted arrangement clearly indicated that the vertical arrangement is preferable in that:

- It provided a more even distribution of light across the workshop.
- It illuminated many of the areas of dark shadow.
- It provided significantly better levels of illumination beneath vehicles (30 lux compared with 1 lux to 5 lux)

Haulage Routes and Travelways

The project examined a range of different haulage routes and travelways in different mines. Details of many of these locations are included in the mobile machine assessments. Assessment details relating to five specific locations examined from the perspective of a person walking into the mine are given below. These examinations cover:

1. A section of main roadway at some point between a station at the bottom of an inclined shaft and the production areas
2. A tractor road between a shaft bottom and the production areas.
3. A winze connecting upper and lower seam levels.
4. Shuttlecar road in a CM section.
5. Pedestrian travelway in a production section.

Location 1. Main Roadway

Operation: Walking into mine

Sources of Illumination: Twin 1,2 m fluorescent 75W tubes spaced at 10m intervals suspended 0,5m from roof in centre of roadway. Tubes were mounted longitudinally along the roadway.

Key Dimensions: Roadway was 7,3m wide x 3,3m high and approx. 0,5 km long. It constituted the main walkway to the section for mineworkers and officials travelling between the shaft and the section. In addition to people, a number of vehicles were seen being driven along the roadway including personnel carriers and LHDs.

Visual Environment: Walls and roof were whitewashed with good reflective qualities.
Ground was dry firmly compacted coal, coloured grey from influence of a light covering of stone dust.

Illuminance 40 lux directly beneath lights, 30 lux at mid point between lights.
20 lux measured directly beneath occasional defective light units.

Visual Conditions Good. No sources of glare, deep shadows or high air velocities.

Blind Spots Roadway passes through old board and pillar workings. There are several 90 degree left and right turns and interconnecting roads. At each turn and intersection there are blind spots

General conditions Floor at side of roadway was littered with small cobble stones (up to 50 mm diameter.)

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Slip/trip/fall at sides of roadway	Poor housekeeping and defective roadway lights
2. Struck by vehicle (from behind or emerging suddenly from turns)	Vehicle horns/whistles - not always provided and not reliably used. Some Vehicle lights defective, some dim when engine revs drop

Location 2. Tractor road

Operation: Travelway for pedestrians combined with haulage route for mobile machines.

Sources of Illumination: Twin 2,4 m x 75W fluorescent lights spaced 25 m apart and suspended longitudinally along the one side of the roadway 1,0m from the ribside close to the roof.

Key Dimensions: Road was 6,0 m wide x 1,8 - 2,0m high and ran 2,5 km inbye from a shaft station to a production section.

Visual Environment: The environment changed noticeably on-route to the section.

In the outbye half of the road the floor was fairly even, slightly damp with occasional areas of light surface water, greyish white in colour and compact. The ribsides had a dry, light covering of stone dust. The sandstone roof was also stone dusted.

The inbye half of the road was characterised by the considerable presence of potholes, deep water and slushy mud up to 300mm deep. In this area the stone dusting on the ribsides was layered to a height of 800mm by mud thrown up by vehicle wheels.

Lights throughout the length of the tractor road were covered in coal dust.

Illuminance No measurements

Blind Spots The tractor road passes through old board and pillar sections involving several sharp turns to the right and left and intersections with conveyor roads. At each turn and intersections there are potential blind spots.

Although direction signs were evident at some of the turns, none were provided at other turns. The condition of the signs ranged from being clear, to dusty, to being covered with mud. (All signs observed were of the reflective type.) Potential for collisions exists at all such corners.

Obstructions While few obstructions were identified in the outbye half of the roadway, many obstructions were identified inbye. These included:

- 2,5m wide sections of a continuous haulage systems left haphazardly along one side of the road.
- Unmarked pumps left in holes filled with water near the side of the road.
- Pipes and cable left lying in the mud at the side of the road.
- The uneven road surface caused vehicle drivers to strike their heads on the roof.

Signs of damage indicated that collisions occurred regularly

General conditions Whereas the outbye section of the road provided a fairly even travel surface, the inbye section, characterised by potholes, mud, poor illumination and obstructions, adversely affected travel conditions and enhanced accident potential.

Deviations from Procedures: The adverse conditions described above clearly reflected an infringement of standard safe working practices.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Collisions with pedestrians, other mobile equipment or parked equipment in roads.	Sight line and illumination limitations on many of the mobile machines used on the mine. Failure to provide workforce with high visibility clothing, fitted with reflective strips. Failure to maintain roadways in reasonable condition. Restrictions in operating clearances due to equipment parked/abandoned in the roadways. Driver's attention distracted when driving over uneven ground. Failure to provide warnings on parked vehicles or equipment. Poor housekeeping standards Failure to provide dedicated parking areas for abandoned/spare equipment
2. Collisions at blind corners (vehicles).	See comments above. No horns or alternative forms of tramming warnings were in use. Roadway signs obliterated by mud
3. Slip, trip and fall in roadway	Failure to maintain roadways in safe condition for pedestrian activity.

Location 3. Winze connecting upper and lower seam levels

Operation: Walking into mine

Key Dimensions: The roadway was 6m wide x 2,5m high and approximately 0,5 km long. It sloped quite steeply downwards towards the lower seam level. It constituted the main walkway and LHD route. Tractors and the occasional grader also used the roadway. A belt conveyor was located on one side of the roadway leaving a 3,5m travelway for the vehicles and pedestrians.

Sources of Illumination: 100W light bulbs suspended 0,5m from the roof directly above the conveyor were spaced every 30m.

Visual Environment: The wall behind the conveyor and roof was a combination of dull coal and dark coloured stone.

The floor was heavily rutted compacted coal or dark coloured stone.

The wall adjacent to the travelway was stone dusted.

Illuminance Measurements taken on the floor in the centre of the travelway:

Directly opposite the lights - 8 lux, mid-point between lights: 0,5 lux

Visual Conditions Poor. Air velocity was low, however, there was considerable dust generation from the conveyor whenever the belt was running. Some lights were defective.

Blind Spots For pedestrians there was a T-junction at each end of the road and a number of intermediate turnings where there were blind spots.

For drivers of LHDs, almost the whole width of the roadway both in front and behind was obscured up to a distance of at least 60m. Travelling forward (bucket leading) up the winze the driver was working virtually blind and had to adopt the side of the roadway or conveyor as a visual cue in order to steer.

General conditions Apart from the rutted condition of the road, there was a lot of loose fines and a litter of small cobbles (up to 50mm diameter).

Deviations from procedures:

Some pedestrians were seen without the reflective waist coats that they should have been wearing.

Potential hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
Slip/trip/fall in roadway	Poor housekeeping and defective roadway lights. Poor reflectance from walls .Loose cobbles on roadway
Struck by LHD (from behind or emerging unexpectedly from turns)	Some drivers fail to sound audible warnings or adequately reduce speed at turnings. Some vehicles were either not fitted with or had no effective audible warnings. Some workers fail to wear reflective apparel Some vehicles were driven with defective headlights

Location 4.Shuttlecar roadway

Operation:	Travelling roadway within the section
Sources of Illumination:	Caplamps only
Key Dimensions:	Roadways were 7,3m wide x 3,3m high. The roadways extended approximately 0,5 km between the feeder breaker and the working headings. The roadways constituted the main travel routes for shuttlecars and were frequently walked by workmen, officials, staff carrying out inspections, etc. Other vehicles such as a scoop (grader) and a stone dusting machine also used the roadway.
Visual Environment:	Walls and roof near the headings were dull with poor reflective properties. Away from the headings, the walls were coated with stone dust, which had poor reflective properties. The ground was loose dry black coal dust.
Illuminance	Caplamp illumination plus varying levels of illumination from different vehicles..
Visual Conditions	Poor: Absence of general lighting, moderate dust levels near the headings, and glare from the machine lights.
Blind Spots	Roadway passes through old board and pillar workings. There are several 90 degree left and right turns and interconnecting roads. At each turn and interconnection there are potential blind spots.
General conditions	In places the floor at side of roadway was littered with small cobbles (up to 50mm diameter). Vehicle tracks, (which provided a firm path along which to walk) was also deeply rutted in places. The supply cables to the shuttlecars are difficult to see.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Slip/trip/fall in roadway	Poor visibility of obstacles and cables in roadway Roadway littered with small cobbles Deeply rutted roadway creates uneven walk surface
Struck by moving supply cables (cables being retracted by vehicles travelling towards the feeder breaker can, under tension, lift rapidly off the ground. Workmen striding over the cables when this happens have been struck).	Poor visibility of cables in the roadway.
Struck by shuttlecars	See separate assessments of shuttlecars

The risk of pedestrians being struck by shuttlecars is dealt with in the shuttlecar assessment.

Location 5. Pedestrian travelway

Key Dimensions: Roadway was 7,3m wide x 3,3m high. The roadway traversed and extended 50m either side of a conveyor belt. Steps and a narrow elevated platform provided the means of crossing the conveyor area. The roadway was frequently used by workmen travelling between the working face and the feeder breaker, officials carrying out inspections and belt attendants and was rarely used by vehicles.

Sources of Illumination Caplamps only.

Visual Environment: Walls were coated with old peeling stone dust.
Roof was dull coal with poor reflective properties.
Ground was flooded with water to a depth of 0,3m and caused some caplamp reflection.

Illuminance Caplamp illumination only.

Visual Conditions Poor: Water obscured slip/trip hazards at ground level; Unpainted metal steps and platform failed to contrast with general background.

Blind Spots Submerged obstacles included lumps of rock/coal up to about 150mm in size and lengths of various-diameter pipe. The ground under the water was also uneven with potholes to a depth of 0,5m. Bottom step to platform was also submerged.

General conditions Some bolts protruded from side walls by 300 mm and lack contrast with background.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

	Control Limitations
Slip/trip/fall over submerged obstructions and ground undulations in flooded roadway.	Roadway maintenance failed to drain off surface water and provide level consolidated walkway. Poor housekeeping standards Failure to maintain proper walkway
Walking into protruding bolts	Impractical to illuminate roadways in production areas. Failure to remove protruding bolts. Workplace inspection sub-standard
Slip/trip/fall negotiating platform	Platform colouring does not contrast with background. Bottom step of ladder to platform submerged

Electrical Sub-stations

Assessment details for three electrical substations are given below. The assessment were undertaken from the perspective of someone working in or walking through the locations.

Sub-station 1.

Key Dimensions: Details of the area in which the sub-station was located are shown in the following diagram. The roadways were 5m wide x 2,5m high.

Sources of Illumination: Originally twin 2,4m x 75W fluorescent tubes suspended from the roof were provided along all the ribsides.
At the time of the assessment these were being replaced by sets of four 1,2m x 40W units with the view towards providing a better standard of lighting. The diagram indicates the progress that had been made.

Spacing between all light units was 1,0m.

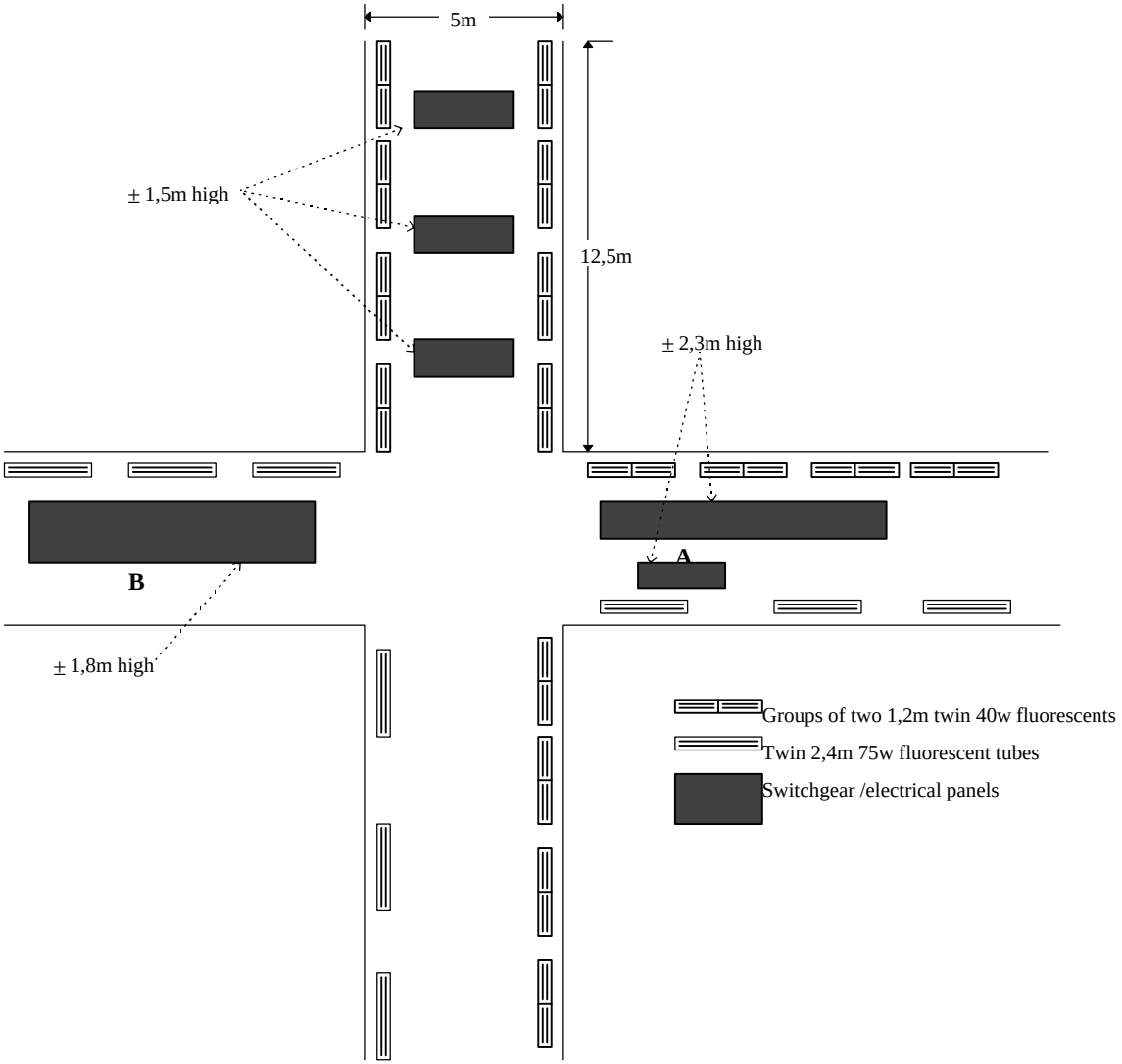
Visual Environment: Walls were constructed from concrete bricks painted white from floor to roof
The floor was concrete painted dark green.
The roof was lined with unpainted galvanised sheeting.
The floor, roof and walls were dry and clean. There was little evidence of coal dust.

Illuminance High levels of illumination were provided at all points in the location. Typically, lighting levels in the order of 600 lux were measured in walkways alongside panels and switchgear.

At point **A** in the diagram between two tall panel boxes, levels of 400 lux were measured at working height approximately 1,0m off the ground.

At point **B** in the diagram between a tall panel box and an unlit ribside, levels of 200 lux were measured 1,0m off the ground.

Visual Conditions Very good throughout the area. There were no sources of glare, areas of deep shadows or blind spots that were likely to have safety implications



Electrical Sub-station 1.

Potential Hazards

No visual limitations were identified that were likely to contribute to the risks arising from any of the inherent hazards that existed in the location.

Sub-station 2.

Key Dimensions: Details of the location are shown in the following diagram. The roadways were 5m wide x 2,5m high.

Sources of Illumination: Three rows of four lights were provided. The lights were 1,2m x 40W twin fluorescent tubes spaced 1,5m as shown in the diagram. The lights were mounted 0,5m from the ribsides and 0,5m from the roof.

Visual Environment: An unpainted steel door led into the location, which was enclosed, on the other three sides by brick walls.

The walls were constructed from cement bricks and were painted white from floor to roof.

The floor was concrete painted dark green.

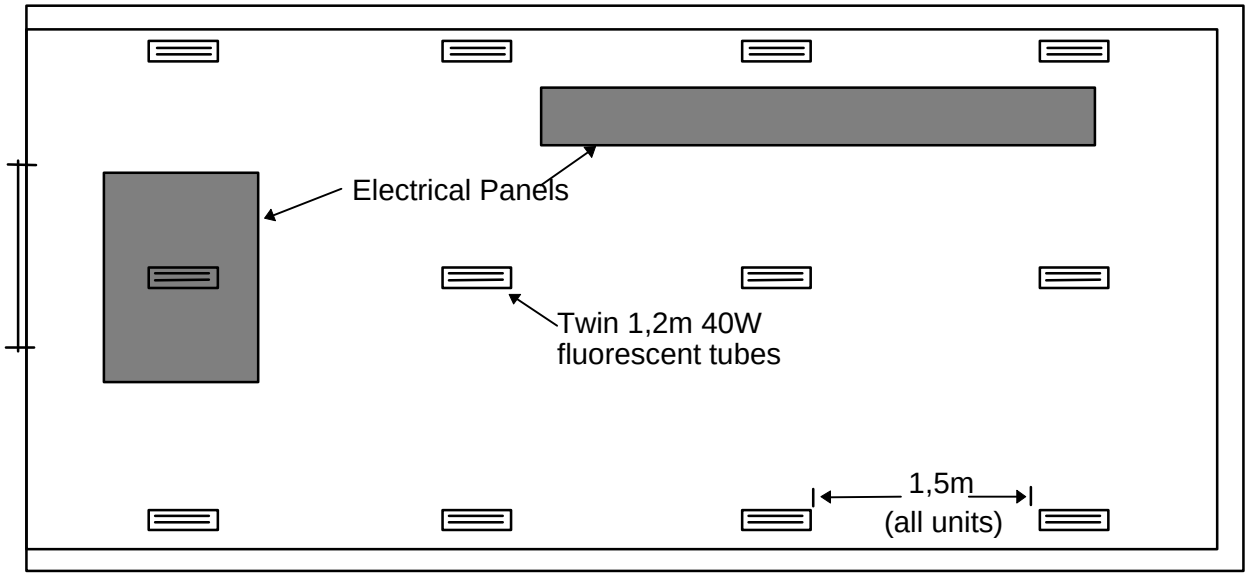
The roof was lined with unpainted galvanised sheeting.

There were two sets of electrical equipment, one was painted orange and the other grey. Both units were 2,2m tall. The whole location was spotlessly clean tidy and dry.

Illuminance Reading taken at working height (about 1,0m off the ground) varied between 300 lux and 500 lux.

Visual Conditions Very good throughout the area. There were no sources of glare, areas of deep shadows or blind spots that were likely to have safety implications

Blind Spots None



Sub-station 2.

Potential Hazards

No visual limitations were identified that were likely to contribute to the risks arising from any of the inherent hazards that existed in the location.

Sub-station 3.

Key Dimensions:

The substation was located in a ‘split’ between two roadways running in parallel. While railings were provided at one end, the other end was open. The ‘split’ was 18m long x 7m wide x 2,0m high.

See diagram below for layout details.

Sources of Illumination:

Three rows of three 1,5m x 65W single fluorescent tubes spaced 4m apart.

The two outer rows were mounted 1,0m from the ribsides. The middle row was mounted down the centre of the ‘split’. All lights were mounted close to the roof.

Two of the lights had been sprayed with red paint.

All light fittings were covered with a thick layer of coal dust.

Visual Environment:

All the electrical equipment was painted white but was covered with a thick layer of coal dust.

The floor was dry and even and comprised a grey/black mixture of coal dust and stonedust.

Sides and roof were covered in dry stonedust, but reflectivity was limited significantly by the presence of coal dust..

The railings at the entrance to the installation painted yellow, but were covered in coal dust.

The lights were also heavily coated in coal dust.

Illuminance

Lighting levels at a range of points in the location are given on the diagram.

Light measurements taken under the middle row of lights 1,0m off the ground indicated 225 lux directly beneath a light and 10 lux between lights ((point **C** on diagram).

20 lux was measured between the rows of lights.

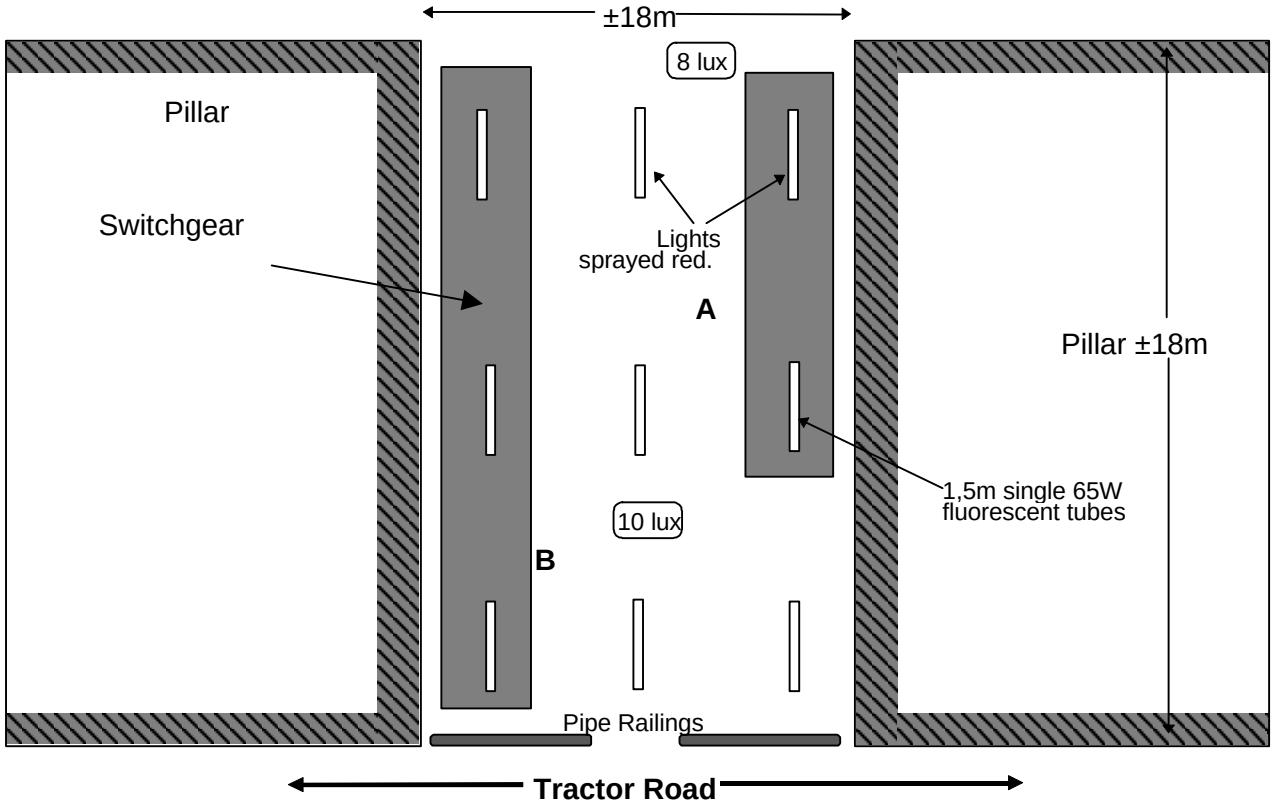
Readings at panels where repair work would be carried out 0,6m off the ground ranged from 1,5 lux to 15 lux (see points **A** and **B** on diagram).

Visual Conditions

The whole area seemed to be in semi darkness due to the amount of coal dust that had settled on the electrical equipment and lights. In particular, the area under the two red painted lights was noticeably darker than elsewhere.

Blind Spots

Electricians complained that they were unable to see inside the electrical equipment. They were unable to simultaneously look and shine their caplamps through the narrow work openings.



Sub-station 3

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Trip/fall hazard in walk areas.	Low levels of illumination due to coal dust covering on lights, walls and equipment. Some lights sprayed red. Dark floor and areas of dark shadow prevents reliable detection of the trip hazards. Failure to keep luminaires clean
2. Danger of injury whilst working on electrical equipment/switchgear due to low luminance.	Inadequate illumination provided to important working areas. Poor housekeeping standards adversely affect illumination levels.

Fuel Stores

Assessment details for two diesel bulk storage bays are given below.

Storage Bay 1.

Key Dimensions:

Layout details of the fuel store are given in the following diagram.

Basically the store was located in an excavation off a main haulage route. The excavation was 9,3m long x 5,5m wide x 2m high. Two railway lines ran centrally into the store. The fuel tank was located in the centre of the excavation. A large hydraulically operated steel door was provided to allow entry of locos. A smaller door for pedestrians was located at the side of the main door.

Sources of Illumination:

Five single 50W 1,5m flameproof fluorescent tubes mounted laterally across the area as shown in the diagram.

Visual Environment:

The walls were lined with unpainted concrete bricks.
The floor was unpainted concrete coloured almost black, layered with shallow puddles of water. The space between the rails was not boarded over.
The roof was black coal.
The light fittings had a faint covering of coal dust
Both doors were sheet metal painted yellow.
The light fittings and doors were coated in a thick layer of coal dust.
Eight red fire extinguishant containers were located in the positions shown (see diagram).

Illuminance

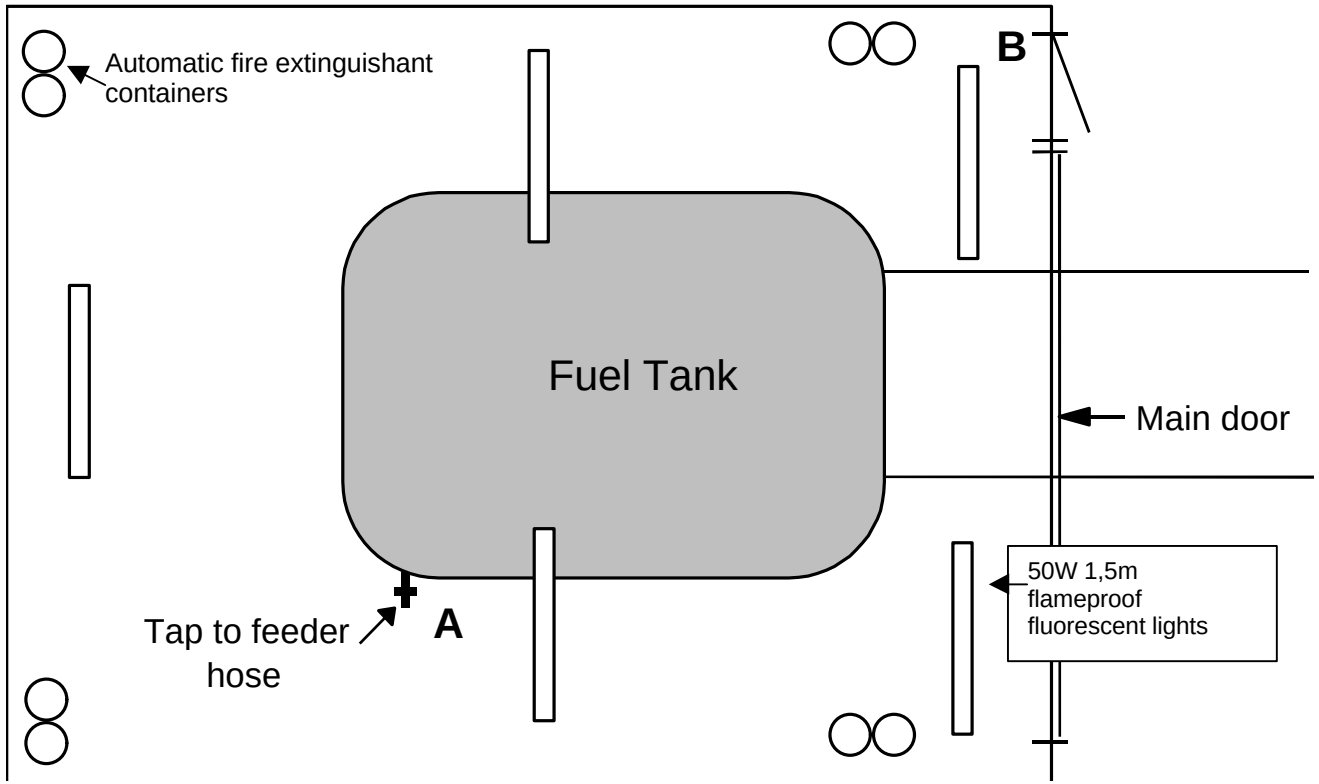
A typical level of illumination in the walkway round the tank was 80 lux.
At the top of the tank, adjacent to where the feeder hose was connected, an illumination level of 70 lux was recorded (point **A** on diagram).
At the controls of the hydraulic pump for the main door (point **B** on diagram) illumination levels of 20 lux were recorded.

Visual Conditions

Due to the absence of reflective surfaces there were large areas which seemed dark, particularly at the locations where there were potential tripping hazards e.g. near the control for the main door, behind the doors generally, and especially between the railway lines.

Blind Spots

None



Fuel Storage Bay 1.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Tripping over obstacles behind doors.	Inadequate levels of illumination provided Trip hazard not distinguishable (covered in coal dust and lack colour contrast with background)
Spillage of fuel when connecting or disconnecting feeder hose to the tank.	Poor standard of illumination at connection point.
Caught by hydraulic door opening or shutting	Poor levels of Illumination at door (areas of dark shadow) Lack of warning of imminent movement of door.
Tripping over tracks	Poor levels of illumination. Failure to board in space between tracks.

Storage Bay 2.

Key Dimensions:

Details for a fuel store complex are shown in the following diagram. The complex incorporates a loco re-fuelling bay and a re-fuelling bay for other mobile machines.

The loco re-fuelling bay was 6,0m wide x 4,0m high. 150mm and 200mm diameter pipes were suspended 2,0m off the ground in the loco haulage route.

The mobile machine re-fuelling bay was 6,0m wide x 2,0m high. A low (0,5m high) wall prevents the machines from being driven through the bay and into the loco haulage route. A fuel dispense (point **C** on the diagram) is used to re-fuel these machines.

Sources of Illumination:

Six single 1,5m x 65W flameproof fluorescent tubes were provided in the mobile machine refuelling area. The lights were mounted in a hap-hazard arrangement and two were defective.

Twin 1,8m x 65W fluorescent tubes, spaced 4m apart were mounted 2,5m above the ground along the centre of the loco haulage route. One of the tubes in the light unit at point **A** directly (above the switches in the track) was defective.

Visual Environment:

The visual environment in the loco re-fuelling bay were virtually identical to those detailed in the previous assessment and have therefore not been repeated. Regarding the other areas:

The walls were concrete bricks either white-washed or stone dusted.

The floors were unpainted concrete coloured dark grey. There were several shallow pools of surface water in the loco haulage route. A length of old black rubber hose lay adjacent to the tracks in the loco refuelling area.

The roofs were similar to the sides i.e. white coloured.

Illuminance

The following illumination measurements were recorded (see diagram):

At point **A** - 40 lux (track switches at ground level in loco haulage route).

At point **B** - 20 lux (mid-way between the light units in the loco haulage route).

At point **C** - 2,5 lux (at the fuel dispenser for mobile machines).

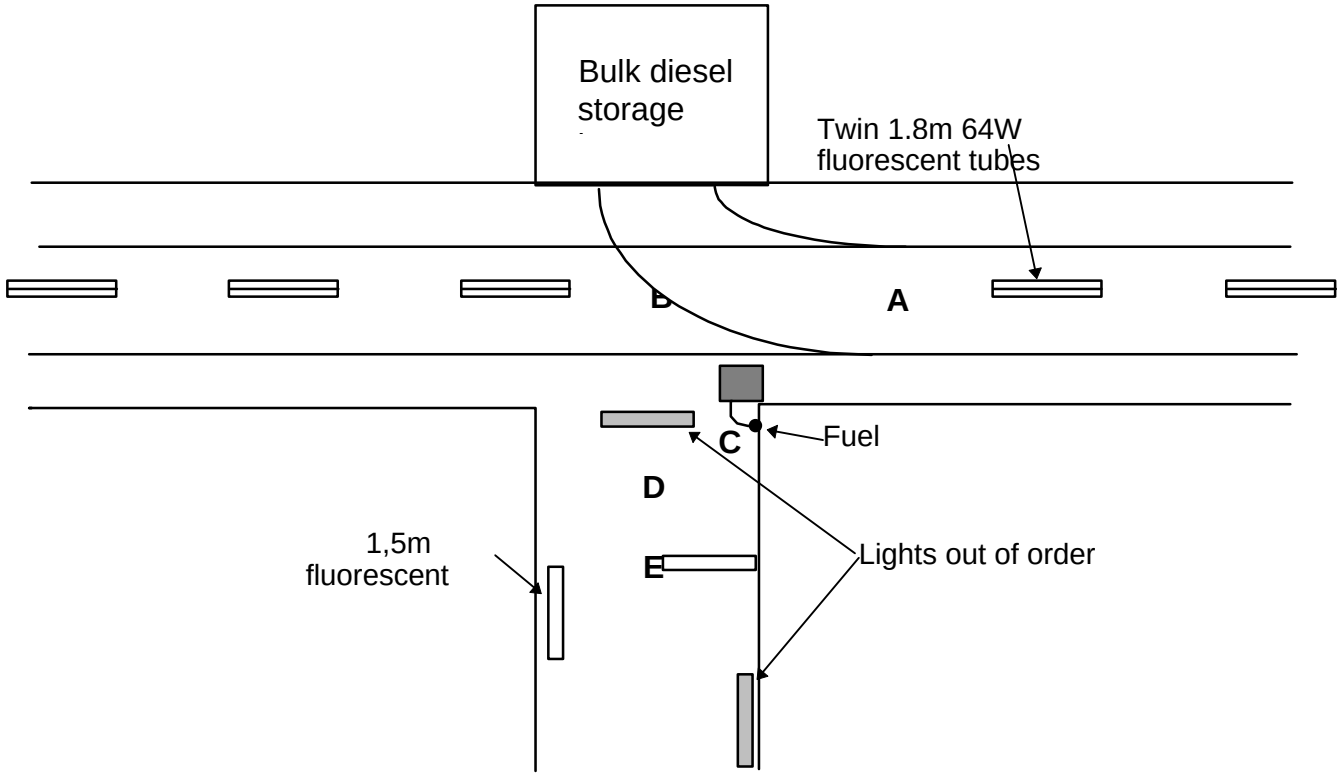
At point **D** - 5 lux (spot where mobile machines park to re-fuel.)

At point **E** - 12,5 lux (reading between lights in mobile machine re-fuelling bay).

Defective lights create unnecessary areas of dark shadow at critical points. Also, surface water conceals potential tripping hazards and potential track defects.

Blind Spots

None



Fuel Storage Bay 2.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Tripping and falling.	Defective lights create unnecessary areas of dark shadow. Failure to remove obstacles from floor (poor housekeeping). Pools of water obscure tripping hazards/deterioration in track conditions. Failure to board-in spaces between tracks.
Loco derailments and collisions	Visibility of points affected by defective light units. No switching device provided at points.

	Potholes developing between tracks concealed by pools of water

DYNAMIC LOCATIONS

Dynamic locations are areas where it is impractical to provide fixed lighting installations and hence portable, transportable, or on-machine lights may be required. Dynamic locations are, therefore, typically associated with productions areas which are constantly advancing. Assessment details for many of the dynamic locations identified by the project have already been considered in the mobile machine assessments. For example, the visually related factors associated with advancing long and shortwall faces were examined in the shearer assessments. Given the highly interactive nature of these two face activities, it was considered more beneficial to combine these two areas of consideration within a single assessment rather than 'artificially' isolating them in separate assessments in different parts of the appendix. Similarly, assessment details relating to CM sections, stooping sections and conventional drill and fire sections are included in the assessment details covering the machines used in those sections. Feeder breakers were for instance dealt with in shuttle car assessments. However, for completeness, this section contains assessment details for a number of additional dynamic locations that were identified and singled out for individual consideration.

Each assessment contains:

- Description of the operations undertaken.
- Key dimensions.
- Sources of illumination.
- Assessment of the visual environment
- Significant potential hazards associated with the visual limitations identified.

In addition, where it was possible to observe activities being undertaken, the assessments also contain:

- Task descriptions.
- Identification and assessment of visual targets.
- Critical visual attention areas
- Assessment of the visual environment for each visual attention area.

Production Faces

Assessment details are given below for two operations undertaken in conventional drill and shot-fire sections which have not been adequately dealt with in the mobile machine section. These operations are:

1. Inspecting and preparing the face prior to loading; cutting; roofbolting; drilling; setting charges.
2. Hand drilling the face.

Inspecting and preparing a Face

Operation: Normally two workmen are involved in this operation. Basically the task involves inspecting the roof and sides for loose or friable material, inspecting the face for misfires, and testing for gas.

Key Dimensions: Typically, a section size would be 6,0m wide x 3,5m high and pillars would be 20m wide.

Sources of Illumination: In most cases caplamps provide the only source of illumination. Occasionally there is some illumination from the lights from machines working in the area.

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Prepare face for bolting		
Enter and make preliminary assessment	VT1 Obstacles on the ground VT2 Loose coal on face VT3 Fractures and loose conditions in roof VT4 Loose coal on ribsides	2, 3
Examine for gas using portable methanometer	VT5 Socket holes, drilled holes, cuts, pockets in roof VT6 Methanometer display	1, 2, 3
Examine for misfires	VT7 traces of unfired explosive VT8 Detonating wire VT9 Drilled holes	2, 3, 4
Bar down roof and sides and check roofbolts	VT2, VT3, VT4	2, 3
Hang methanometer in heading	VT10 Roofbolt	
Set temporary supports	VT1, VT2, VT3, VT4	2, 3

Assessment Details

Visual Targets:	Obstacles on the ground [VT1] Loose coal on face [VT2] Fractures and loose conditions in roof [VT3] Loose coal on ribsides [VT4] Socket holes, drilled holes, cuts, pockets in roof etc. [VT5] Methanometer display [VT6] Traces of unfired explosive [VT7] Detonating wire [VT8] Drilled holes [VT9] Roofbolt [VT10]
Operational Blind Spots:	Concealed cavities (only identifiable by tapping); explosive in holes.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamps only
Reflectance-	Minimal, walls, roof and floor are all coal and no other reflective items in working area.
Contrast-	Most of visual targets were part of coal background i.e. cracks, loose material, etc.
Visual conditions-	See workmen's comments below
Classification-	Identification/course tracking
Operators comments-	Caplamps were not considered adequate.

Deviations from Procedures:
Methanometer was not used at roof level when preparing face for cutting.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Gas explosion on face.	Unreliable monitoring of methane levels (due to difficulties in reading methanometer at roof level)
2. Fall of coal when inspecting and preparing face for subsequent operations.	Poor contrast visibility of visual targets
3. Tripping and falling.	Poor vision and lighting impairs detection of potential trip hazards
4. Failure to detect misfires	Poor vision and lighting

Hand Drilling

Operation:

Activities involving use of an electric powered handheld drill. The face had previously been inspected and prepared as detailed in the previous assessment.

Fifteen 2,35m length holes were drilled in each face.

The face had previously been marked for drilling with chalk.

Key Dimensions:

All roadways, intersections and faces in the section where the assessment was undertaken were 6,0m wide x 3,5m high and the pillar width was 20m.

The drill was a 1,1kW unit weighing 30Kg having an operating speed of 535 RPM. The drilling team consisted of two men. Both men supported the drill together during drilling.

The working platform was approximately 1,2m x 1,2m x 1,5m high. Steps were provided up the side, however, there were no handrails provided to prevent men from falling off the work platform. The floor of the platform was chequer plate.

The men worked on their knees on the ground when drilling the bottom row of holes

Sources of Illumination:

Caplamp illumination only.

Visual attention areas when drilling

Visual Targets:	Roof and sides (VT1) Dust catcher to ensure that it is in position (VT2) Floor of platform i.e. edges and any slip/trip hazards lying thereon (VT3) Alignment/angle of drill (VT4) Gripping points on drill (VT5) Steps on side of platform (VT6)
Operational Blind Spots:	None, although one of team claimed that his eye protectors become so dirty that he was essentially working blind. Also, having to concentrate on drill, they were unable to look at the floor of the platform.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	Caplamps only
Reflectance-	All workmen in white hard hats, dark blue overalls, and reflective yellow waist coats. Drill was white painted but coated in heavy layer of coal dust. Supply cable was black. Working platform was painted a dark colour Visual targets on face were part of coal background i.e. cracks, loose material, etc.
Contrast-	Viewed against: Ribsides and roof dry dull coal. Floor damp coal but not muddy.
Visual conditions-	Poor. Considerable dust was created when drilling which, coupled with the restricted vision through dirty eye protection, tended to partially obscure most of the visual targets.
Classification-	Identification/course tracking
Operators comments-	One of the team claimed that his eye protectors become so dirty that he was essentially working blind.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Hit by falling face/roof material	Poor contrast visibility of visual targets Dirty eye protectors obscure visual targets.
2. Falls from platform	Lack of safety rails Poor contrast visibility of platform with ground
3. Caught up on drill rod	Poor vision and lighting Dirty eye protectors obscure visual targets.
4. Slip trip fall in roadway	Poor vision and lighting Dirty eye protectors obscure visual targets. Low reflectance and hence poor contrast of power cable with ground
5. Hand/arm injuries when drill stalls	Poor vision and lighting Dirty eye protectors obscure visual targets.

Gate Ends, Gate Roads and Conveyor Roads

Stage Loader

Operation: A Matilda stage loader operating in the main gate of a shortwall face was used to transfer product from the face AFC to the belt conveyor system in the gate road. This assessment focused on the activities undertaken by the stage loader attendant, whose main responsibility was to continuously monitor satisfactory operation at the discharge point i.e. checking for blockages, spillage, presence of excessively large lumps, operation of the water sprays, and damage to the stage loader and conveyor belt.

Key Dimensions: The gate road was 6m wide x 3,0m high. The belt system was located to one side. A steel cabin was located on the wider travelway side of the road close to the discharge point. The cabin had been provided for stage loader attendants as a place of safety from which they could observe operations. The emergency stop control was located in the cabin.

Sources of Illumination: A Victor VX-6/0900174, 20W 0,5m long flameproof fluorescent light tube was mounted on the front of the cabin approximately 1m off the ground. A similar unit was mounted above the platform over the stage loader approximately 10m inbye. Caplamps were the only other source of illumination.

Task Description

The attendant was responsible for monitoring conditions, stopping the system whenever a problem arose and helping to rectify the problem. No problems arose during the study so it was possible only to assess monitoring activities. Monitoring activities were straight forward in that all that the attendant was required to do was stand in the cabin, watch the discharge point for problems, and 'hitting' a push-button in the cabin to stop the system whenever a concern arose. Openings (unglazed windows) enabled the attendant to see the belt.

Visual Attention Area

There was essentially only a single visual attention area, which encompassed the specific visual targets itemised in the following table:

Visual Targets:	The stage loader chain and product at the point of discharge (VT1) The first 2 or 3 metres of conveyor belting and product (VT2) Lumps flung from above conveyance (VT3) The floor of the heading under the discharge point (VT4) Stop control (VT5)
Operational Blind Spots:	While the observation cabin was brightly lit, the visual attention area was in deep shadow. Looking from such well lit position into a darkness had the effect of creating the whole visual attention area into a blind spot.
Major Postural Changes:	None
Visual Environment:	
Illuminance-	10 lux measured at point of discharge 20 lux measured on conveyor belt 250-300 lux measured inside the cabin.
Reflectance-	Poor, Product on belt was damp coal and conveyor structures were dark painted.
Contrast-	Viewed against: Main roadway ribsides were coated with stonedust with poor reflective properties. Floor was dry compacted coal dust and was damp in places.

Visual conditions-	Despite the presence of water sprays, a considerable amount of dust was created due to a failure to adequately dampen product on face. The attendant was also exposed to a regular shower of lumps thrown from the conveyor. These issues and the blind spot described above, combined to create very poor visual conditions and the deviation from the stipulated working practice described below
Classification-	Identification and course tracking
Operators comments-	See below

Deviations from Procedures:

1. The attendant frequently left the security of the cabin and stood close to the discharge point where he was at risk from being struck in the face by stones and the loose end of the belt if a break occurs. Furthermore, in this position he was 2 to 3m away from the emergency stop and would not have been able to react rapidly in an emergency. He claimed that he needed to adopt this position to overcome the visual restrictions outlined above.

3. Despite frequently being struck in the face, the attendant often removed his eye protection. He claimed that when adopting the above position they got splattered in mud and further impaired his vision.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Struck in face by items of product thrown from the discharge	Safe working position compromised by: • Poor standard of illumination • Failure to suppress dust. • Failure to use PPE consistently
2. Struck by end of broken belt	As above
3. Failure to stop conveyance rapidly in emergency situation	Prescribed working position compromised by: • Poor standard of illumination • Failure to suppress dust.

Main-gate Roadway

Operation: Travelling main gate roadway

Key Dimensions: Roadway was 6m wide x 3m high. A conveyor system ran along one side of the roadway. The remainder of the roadway was used by pedestrians travelling to and from the face and by belt attendants. The roadway was approximately 1,0 km long.

Sources of Illumination: Caplamps only.

Visual Environment: Walls were coated with old stonedust with poor reflective properties.
Roof was dull coal.
Ground was compacted coal, however, there were large areas of water up to 100mm deep which caused some caplamp reflection.

Illuminance Caplamps only

Visual Conditions Poor: Water obscured slip/trip hazards at ground level.

Blind Spots Submerged hazards included lumps of rock/coal and lengths of 75mm diameter pipe. The ground under the water was also uneven with pot holes up to a depth of 0,3m.

General conditions Some bolts protruded from the side walls by up to 0,3m and lacked contrast with the background. There was also a proliferation of wooden chocks, wedges, etc. lying on the ground.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
Slip/trip/fall in roadway	Poor visibility of concealed hazards in roadway poor. Poor maintenance of travelway Poor housekeeping standards Inadequate illumination provided
Walking into protruding roofbolts	Inspections fail to identify and remove protruding bolts Inadequate illumination provided Poor maintenance of travelway

Changing Conveyor Belt Roller

Operation: Replacing a conveyor belt roller

Key Dimensions: The belt road was 2,5m high x 6m wide. The conveyor system ran along one side of the roadway. The remainder of the roadway was used as a travelway by pedestrians. A large diameter pipe range ran along the floor of the roadway next to the conveyor. Workmen had to stand on this pipe while working on the conveyor. The roadway was approximately 1,0 km long and there was a lock-out for the conveyor at each end of the roadway.

Sources of Illumination: Single 100W light bulbs were suspended 0,5m from the roof every 16m along the length of the roadway. The lights were above the side of the conveyor, next to the travelway.

The lock-out where the assessment was undertaken was located at a transfer point where a number of fluorescent tubes were provided.

Hierarchical Task Description

Task Elements	Visual Targets	Hazard No.
Lock-out conveyor		
Walk along conveyor road to lock-out box, approx. 0,5 km	VT1 Walkway	1
Operate lock-out	VT2 Lock-out box	
Secure by removing key	VT2	
Walk back to work area	VT1	1
Remove worn roller		
Lever up belt with pinch bar and chock	VT3 Pipe range on floor of workplace VT4 Area under belt including near and off side rollers	2, 3
Insert pinch bar under near end of roller and prise out	VT3, VT4.	2, 3
Install new roller		
Insert new roller	VT3, VT4	2, 3
Tap in place	VT3, VT4	2, 3
Remove lockout (repetition of locking out in reverse)	VT1, VT2	1
Check for correct operation	VT5 Check for correct belt running/alignment	

The visual targets identified above were grouped into the following visual attention areas**:**

Walkway between damaged roller and lockout box

Visual Targets:	Walkway VT1
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Visual angle-	Trip hazards (approx. 100mm at 2,5m)
Illuminance-	80 lux adjacent to lights 5 lux between lights Zero adjacent to defective bulbs
Reflectance-	Side walls dry with old coating of stone dust with low reflective properties. Floor dry compacted coal dust with scattering of loose cobbles.
Contrast-	Very low, obstacles same colour as walkway
Visual conditions-	Presence of airborne dust from conveyor. Settling of dust on lights restricts output levels. One in three lights defective.
Classification-	Detection
Operators comments-	Occasionally stumble over items on floor.

Lockout box

Visual Targets:	Lock-out box VT2
Operational Blind Spots:	None
Major Postural Changes:	None
Visual Environment:	
Visual angle-	Trip control (approx. 50mm at 1m)
Illuminance-	25 lux measured at lock-out control.
Reflectance-	Painted orange but covered in layer of coal dust
Contrast-	Fair, no apparent problems
Visual conditions-	Presence of airborne dust when lock-out is put on (dust settles by time lock-out is removed). Settling of dust on lights restricts output levels.
Classification-	Medium tracking
Operators comments-	No perceived difficulties

Conveyor belt and rollers

Visual Targets:	Area under belt including near and off side rollers VT4 Pipe range on floor of workplace VT3 Belt and rollers where work was undertaken (to inspect satisfactory operation) VT5
Operational Blind Spots:	None
Major Postural Changes:	None (work undertaken in bent/stooped posture).
Visual Environment:	
Visual angle	Roller extending across conveyor at a distance of 1m. Pipe diameter of 150mm at a distance of 1-1,5m Roller and belt extending across conveyor at a distance of 2-3m.
Illuminance-	Essentially caplamp illumination only when working under belt (VT3). Illumination levels for VT4 and VT5 were essentially the same as for VT1 i.e. 80 lux adjacent to lights 5 lux between lights Zero adjacent to defective bulbs
Reflectance-	Low: belt was black; conveyor structure and pipe range were dark painted; rollers were worn shiny.
Contrast-	Very low, plant same colour as walkway
Visual conditions-	Average. When task was undertaken between lights, workmen relied entirely on caplamp illumination. Caplamp illumination was also essential whenever releasing and inserting rollers.
Classification-	Identification/Course tracking
Operators comments-	Can do the work using caplamp only but replacement of damaged bulbs and routine cleaning of dust from bulbs would be beneficial.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1 Slip/trip/fall travelling along walkway	Limited levels of illumination from defective lights. Tripping hazards not removed. Poor reflectance from walls and roof. Poor housekeeping standards
2 Slip and fall off pipe range while replacing roller	See above
3 Possible hand injuries whilst working under belt e.g. traps involving use of pinch bar, contact with sharp edges, etc.	Workmen have to rely on caplamp illumination when working near defective lights. Limited lighting levels to illuminate items located under belt.

Feeder Breaker

Feeder breakers were examined from the perspective of shuttle car drivers in the mobile machine section of this appendix. The assessment given below, however, examines a feeder breaker from the perspective of workmen routinely employed in that area.

Operation Workmen were observed clearing spillage by shovelling it onto the belt.

Key Dimensions: A diagram showing the layout of the feeder-breaker is given below.

The feeder breaker was located at an intersection of roads measuring 6,0m wide x 1,8m high.

At the intersection roof height was 2,8m.

The belt drive was adequately guarded.

Sources of Illumination: A single 1,5m, 65W Victor fluorescent light was positioned across the tip near the brattice cloth screen shown in the diagram.

Visual Environment: The floor was covered by slushy coal dust to a depth of 250mm. (These ground conditions extended to the working faces in the section.)

Ribsides were coated in old stonedust that had poor reflective properties. The walls had also been heavily splattered with mud thrown up by the wheels of shuttlecars. Some spalling had taken place exposing coal.

The roof was coated in old stonedust that had poor reflective properties and was peeling in places to expose grey sandstone.
The brattice screen was dark grey/black in colour.

Illuminance The following lighting levels were recorded:

At point **A** in the diagram on the belt directly under the light source, a level of 100 lux was recorded (1,0m below the light).

At points **B** in the diagram at the sides of the feeder breaker, levels varying between 2 lux at ground level and 10 lux 1,0m above the ground were recorded.

At point **C** at the end of the tip a level of 6 lux was recorded.

At point **D** at the telephone a lighting levels were too low to measure.

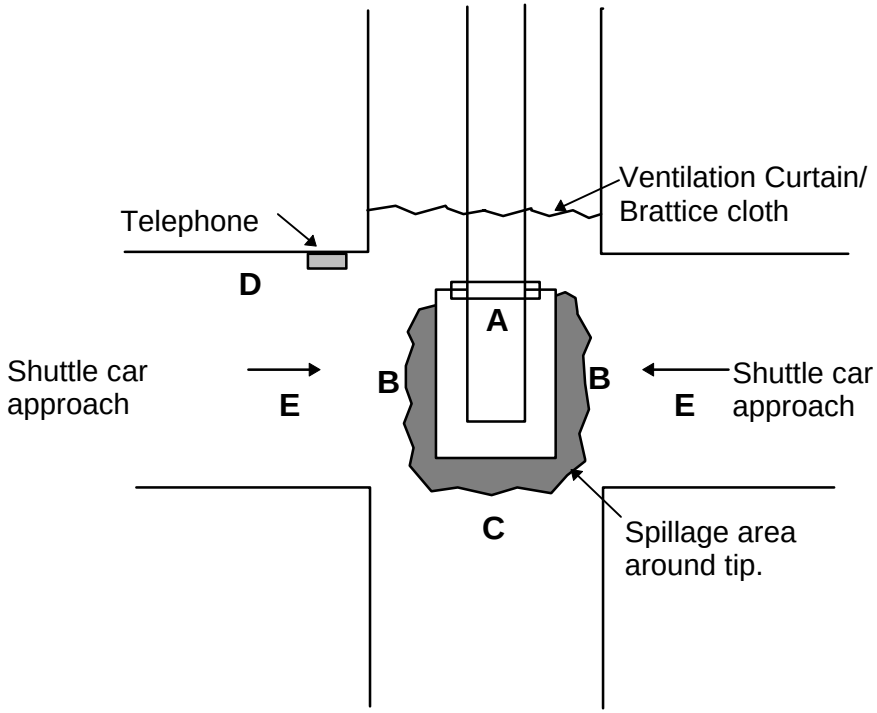
Lighting levels in the roads approaching the feeder breaker were zero (points **E**).

Lights mounted on one shuttlecar approaching the feeder breaker provided illumination levels across the roadway of 4 lux at 20m metres. The right headlight on a second shuttlecar was damaged and was directed at the roof 6m ahead.

Visual Conditions Apart from point **A** the whole area was dark with the ribsides and the sides of the feeder breaker covered in thick mud. Deep shadows permeated the whole area. The notice containing safety instructions and safe operating procedures was located in such shadow.

Supply cables and obstacles were submerged in mud.

The single fluorescent light was covered in coal dust.



Feeder Breaker

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Tripping over hazards engulfed in mud.	• Limited lighting failed to adequately illuminate important critical visual targets. • Poor reflectance from walls and roof. • Failure to control the presence of ground water. • Restricted lines of sight for shuttlecar drivers. • Lights on shuttlecars fail to meet regulatory requirements. • Poor standard of stone dusting • Workmen not provided with high visibility clothing with reflective strips • Failure to clean lights • Poor inspection and maintenance of lights on shuttlecars
2. Shuttlecar collides with feeder breaker.	
3. Tip attendants struck by shuttlecar	
4. Tip attendants struck by movement of shuttlecar cable.	

Miner’s Boxes.

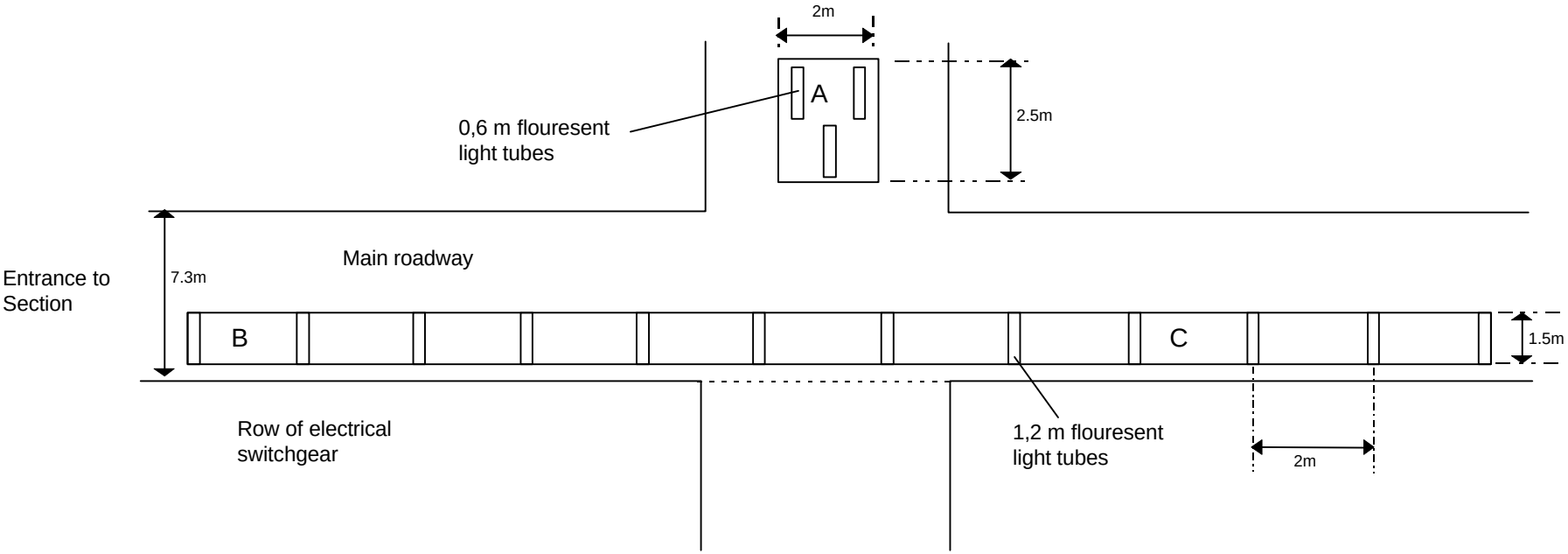
Assessment details for the following three specific, but typical, miner’s boxes are given below.

1. A miners box which also constituted a waiting area within which electrical switchgear for the section was located.
2. A miners box which also constituted a waiting area.
3. A miner’s box, electrical switchgear and engineering toolbox/storage units mounted on sledges.

Following the assessments, significant factors from examinations of other miner’s boxes are given.

Location 1. Miner’s box, waiting area and electrical switch gear at entrance to section

Key Dimensions:	See diagram below: The miner’s box **A** (portable ‘office’ unit of steel construction incorporating bench seats, table and cupboards used by the miners) was located in the entrance to a turning off a main roadway to the section. The roadway was restricted to pedestrians. Road and turning were 7,3m wide x 3,3m high. Main electrical switchgear **B** for the section was located down one side of the road. (The switchgear was mounted on sleds to enable it to be dragged forward as the section advanced). The roadway constituted a main travelway for workmen, officials, staff entering and leaving the section. A workbench and vice **C** was located amongst the switchgear where light maintenance tasks were undertaken.
Sources of Illumination:	Three 0,6 m (2 ft), 75W fluorescent tubes mounted approx. 1,0m above the miners box as shown in the diagram. Series of 1,2 m (4 ft), 75W tubes suspended 1,0m from the roof spaced between individual items of switch gear as shown in diagram. There was no additional lighting provided in the roadway
Visual Environment:	Walls were whitewashed and had good reflective properties. The ground was fine dry coal dust coloured grey from influence of light covering of stone dust.
Illuminance	10 lux measured at isolating handles and access covers on side of control gear. 120 lux on top surface of control gear. 80 lux measured in centre of workbench.(point **C** on diagram) 70 lux measured in centre of roadway. 200 lux measured on table in miners box. (point **A** on diagram)
Visual Conditions	Good. No sources of glare, dust, deep shadows or high air velocities.
Blind Spots	None
General conditions	Good. Ground clear of obstructions; no slip/trip/fall hazards; light maintenance work undertaken on bench and to switchgear should not be compromised by any visual limitations.



Miner's box, Waiting Area and Electrical Switch Gear at Entrance to Section

Potential Hazards

The levels of illumination combined with the high standards of maintenance and housekeeping, etc. should reduce the risk of accidents in the area to a level that is as low as is reasonably practicable.

Location 2. Miners Box and Waiting Area

Key Dimensions: See diagram below:

The miner's box and waiting area were located in a Tee junction at the entrance to a stooping section. Men waiting to enter the section at the start of the shift congregated under the warning signs shown in the diagram.

The roadway was not restricted to pedestrians in that personnel carriers (Jeeps and Mega-Cruisers) frequently drove through the area.

Sources of Illumination: Three 1,5 m fluorescent 65W tubes mounted as shown in the attached diagram.

Visual Environment: Walls were stone-dusted and had reasonable reflective properties. The ground was fine dry coal dust coloured grey from influence of light covering of stone dust.

Brattice cloth behind the miner's desk was black.

None of the warning notices were fluorescent and all were partially concealed by a thin film of dust.

Illuminance A series of light measurements were taken. The measurements are indicated on the diagram. The principal lighting levels were:

20 lux at the miners desk.

10 lux at the waiting area beside the row of warning signs.

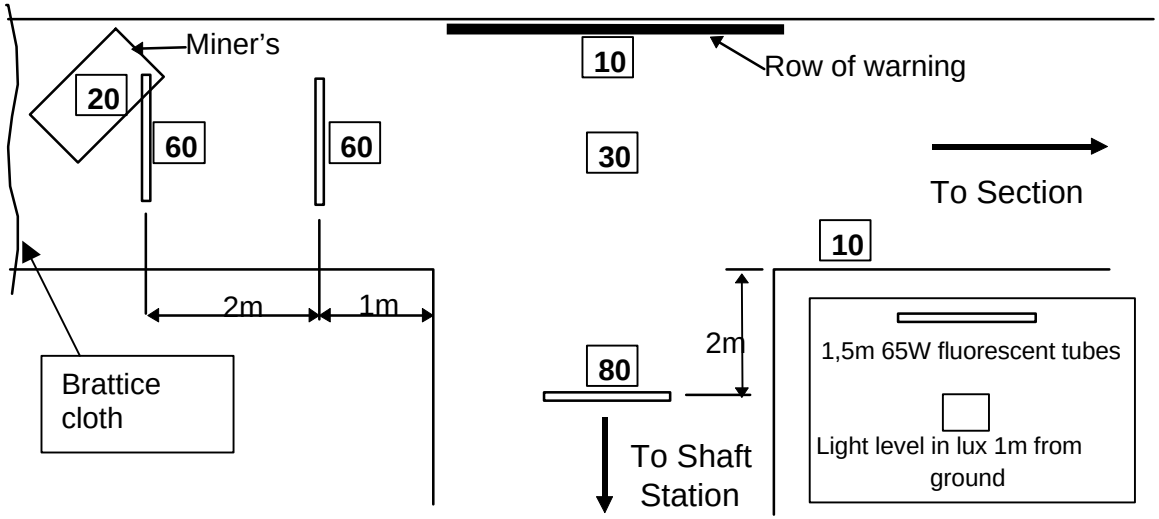
30 lux in the centre of the junction.

10 lux round the corner of the entrance road into the section where there was a minor risk of workmen being struck by a personnel carrier entering the section.

Visual Conditions Good. No sources of glare, dust, deep shadows or high air velocities.

Blind Spots None

General conditions Good. Ground clear of obstructions, no slip/trip/fall hazards. Safety should be not compromised by visual limitations.



Miners Box and Waiting Area at Location 2.

Potential Hazards

The levels of illumination combined with the high standards of maintenance and housekeeping, etc. should reduce the risk of accidents in the area to a level that is as low as is reasonably practicable.

The following two points were however made by one of the mine officials.

1. The feasibility of using white (or a more reflectively coloured) brattice cloth material should be considered for use in the mine.
2. Warning notices should be made from reflective more attention gaining material, especially those notices that have to be seen by vehicle drivers i.e. notices that need to be seen at a greater distance.

Location 3. Miners box electrical switchgear unit and toolbox/storage units.

This assessment concentrates on the toolbox/storage units

Key Dimensions:

A miners box, four toolbox/storage units used by artisans, and an electrical switchgear unit were mounted on sleds and comprised a train of mobile units that could be dragged forward to keep station with a production section. The arrangement is shown in the following diagram.

Each toolbox was 3,0m long x 1,8m wide x 1,4m high. The four units were mounted on a single sled 0,5m to 0,8m apart.

The “train” was located along one side of a main belt road on the opposite side to the conveyor. The roadway was 6,0m wide x 2,0m high.

Sources of Illumination:

A single 1,5m (5 ft) 40W fluorescent tube was mounted on each toolbox as shown in the diagram.

There was no additional lighting provided in the roadway.

Visual Environment:

Sides and roof of the tunnel were stonedusted but reflectance levels were limited by the presence of coal dust.

The conveyor structure was dark coloured and heavily coated in coal dust.

All four tool box units were painted dark green or dark red. The painted surfaces were partially corroded and covered with black coal dust.

The platforms were substantially covered in black mud and in places the original white paint had been eroded.

The travelway between the conveyor and the train of units was black wet coal dust and there were some shallow pools of surface water. Although the ground was generally level there were some wheel track undulations.

Illuminance

The following illumination levels were measured at the door handles of the tool boxes approximately 1,0m off the ground. See diagram for locations:

1 lux Point A

1 lux Point B

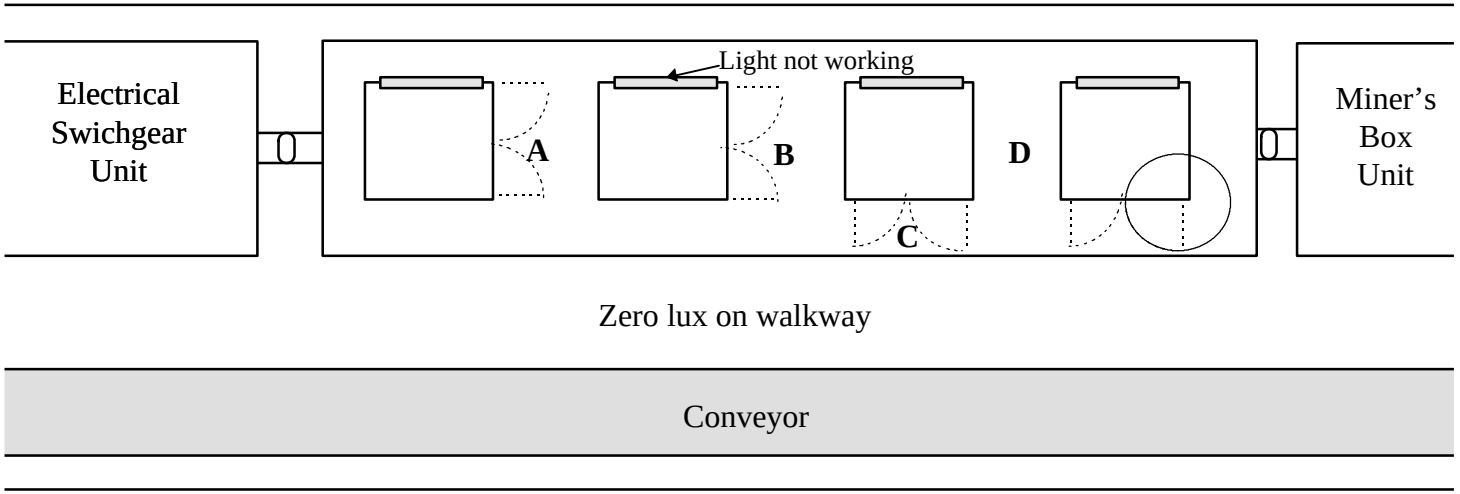
1 lux Point C

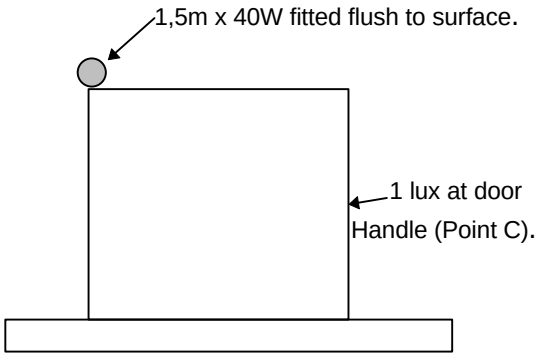
40 lux Point D

Zero in the travelway between the conveyor and the toolboxes at ground level.

Note the reason for the 40 lux at point D was that the lights were mounted close to the ends of the two boxes as indicated in the side view diagram, and both lights were working.

The lights were installed on the wall side of where the unit was located on top of the toolboxes. As a result the light obscured by the toolboxes resulting in a zero reading in the walkway past these toolbox units.





Side view of electrical switchgear panel

Miner's Box, Electrical Switchgear and Toolboxes at Location 3.

Potential Hazards

The visual limitations identified above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Hand injuries whilst removing and returning equipment.	Light poorly located to ensure proper illumination at the work positions. Failure to maintain lights in working condition
2. Tripping over platform	Lack of illumination at ground level. Poor contrast visibility of step. Failure to maintain lights
3. Trip/slip/fall in roadway.	Poor housekeeping Lack of illumination at ground level Failure to maintain lights Lights poorly located to provide proper illumination in walkway

Significant Factors from other Assessments of Miners Boxes

1. In some cases the general levels and spread of illumination were low, leaving some areas of dark shadow.
2. Steps were provided at the entrance to some miner's boxes. While adequate lighting was provided in the 'office' the steps were not illuminated constituting a potential tripping hazard.
3. While the interior of some miner's boxes is brilliantly lit, no illumination is provided in the roadway outside and workmen experienced difficulties adjusting to the sudden change.
4. Loose obstacles were scattered on the ground around some miner's boxes. Given the situation as described in item 3, these constituted a pronounced tripping hazard.
5. Important instructions for workmen entering sections were obliterated in coal dust.
6. Warning notices produced from non-reflective material were difficult to read.
7. In some mine layouts workmen had to step from a brilliantly lit waiting area into a virtually pitch black haulage road in the section where there was the potential that they could be struck by shuttlecars. There was no opportunity for them to adjust to changing light levels.

Electrical Switchgear Units

Assessment details for electrical switchgear arrangements in two different locations are given below.

Location 1.

Key Dimensions:

The sides of two pillars had been excavated to accommodate two mobile switchgear units. The units were approx. 3,0m long x 1,5m high. Excavations were 1,5m deep and there was a narrow walkway around the back of the units. Most operations on the units were undertaken on the front i.e. on the roadway side. The switchgear was mounted on sleds to enable it to be advanced with the production section.

The roadway was 5,0m wide x 3,3m high and constituted the main walkway to a section for mineworkers and officials travelling between the shaft and the section. In addition to people, personnel carriers and other vehicles were occasionally driven along the roadway.

Location of the two items of switchgear and light units provided in the roadway are detailed in the attached diagram.

Sources of Illumination:

Combination of 1,2 m (4 ft) (there seems to be no standard size light prescribed) 40W flameproof tubes and standard 1,5 m (5 ft) 65W tubes and 1,8 m (6 ft) 65W tubes arranged as detailed in the attached diagram.

Visual Environment:

All roadway walls excluding the areas behind the switchgear were stonedusted
The switchgear was painted white, but was covered in a layer of coal dust
Ground was dry firmly compacted coal coloured dark grey from influence of light covering of stone dust.
Roof was coal

Illuminance

Light measurements are shown on the diagram. The principle measurements were:

60-80 lux on top surfaces of the switchgear (measured against a closed panel)

10 lux on closed panels on roadway side of switchgear.

80-120 lux at ground level in the centre of the roadway directly beneath the light units

Zero at any point in the roadway between the lights

Comments made by an electrician indicated that readings inside open panels were likely to be zero. For this work they were dependant on the use of their caplamps. To do this however, caplamps had to be removed to facilitate the difficult postures that would have to be adopted.

Visual Conditions

Top surfaces of the switchgear were well lit however panels on roadway side were only dimly lit.

Roadway, between the lights, was in virtual darkness.

Blind Spots

Inside of switchgear panels

Obstacles on the floor between the light units could only be seen by caplamp.

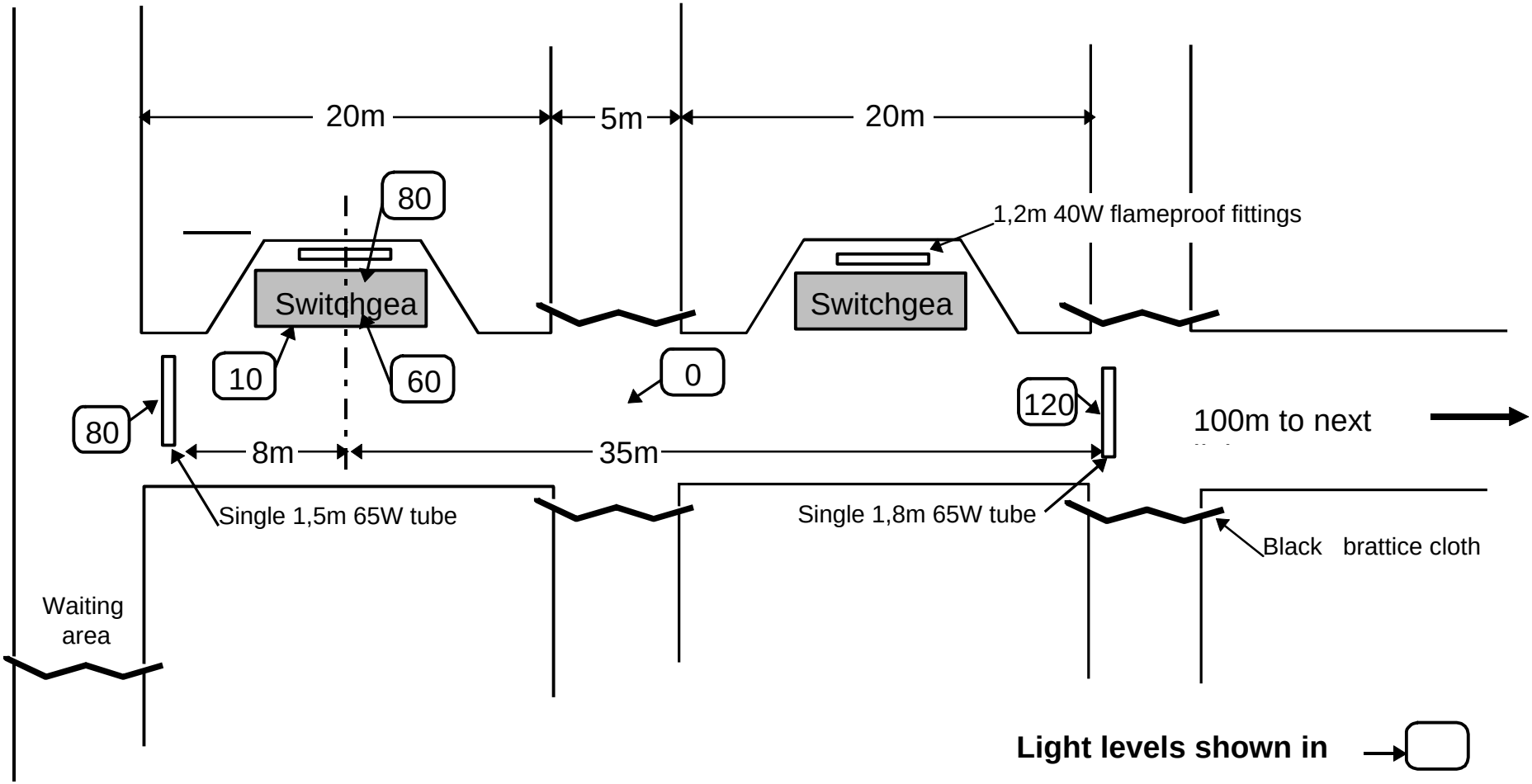
General conditions

Floor was littered with small cobble stones (up to 50 mm diameter.)

Deviations from standard procedures:

According to an electrician,

1. The walls behind switchgear should have been white-washed - this was not the case.
2. Light units should be located in the roadway in line with the centre of each pillar (i.e. every 25m) - this was not the case. In the area studied the lights were spaced between 43m and 100m apart and at the corners of the pillars.



Electrical Switchgear in Location 1.

Potential Hazards

The visual conditions described above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	Control Limitations
1. Slip/trip/fall in roadway	Poor housekeeping Failure to meet specified lighting provision
2. Electricians electrocuted and/or sustain hand injuries working on switch gear	Lack of illumination at access panels and inside switchgear panels. Access restrictions limit sight lines and effective use of caplamps. Restricted workspace results in adopting difficult work postures.

Location 2. (mobile type switchgear on skid)

Key Dimensions:

Two panels of electrical switchgear were mounted on a flat 3,0m long sled. The sled was designed to be coupled to other sleds carrying toolboxes and miners boxes, etc.

The unit is located in a main belt road on the opposite side to the conveyor. The roadway was 6,0m wide x 2,0m high.

Sources of Illumination:

A single 1,5m (5 ft), 40 watt fluorescent tube was mounted on each switchgear unit.

Visual Environment:

The sides and roof of the tunnel were stone dusted but reflectance levels were limited by the presence of coal dust.

The conveyor structure was dark coloured and heavily coated in coal dust.

All switchgear units were painted white but were heavily coated in coal dust.

The platform was substantially covered in black mud and in places the original white paint had been eroded.

The travelway between the conveyor and the switchgear was black wet coal dust and there were some shallow pools of surface water. Although the ground was generally level there were some wheel track undulations.

Illuminance

The following illumination levels were recorded:

1 lux inside an open panel (where work was in progress).

60 lux on top of the switchgear directly under a light unit.

5 lux directly in front of a closed panel.

Zero in the walkway between the conveyor and the switchgear at ground level.

Visual Conditions

All lights were covered with coal dust and emitted only a fraction of their potential output.

Deep shadows existed over and in between the switchgear panels. The interior of the panels were in complete darkness. Electricians had to remove their caplamps and used them to see inside when carrying out repairs (it was completely dark inside switch panels).

The lights were mounted on the wrong sides of the switchgear (i.e. on the opposite side to the doors) to be of any real benefit.

Blind Spots

Workmen were unable to see inside the panels

Obstacles on the ground in the travelway were obscured

The platform step was obscured.

Potential Hazards

The visual conditions described above were judged to make a significant contribution to the risks arising from the following potential hazards:

Potential Hazards	**Control Limitations**
1. Slip/trip/fall in roadway	Poor housekeeping Lack of illumination at ground level
2. Trip over platform	Lack of illumination at ground level. Poor contrast visibility of step
3. Electricians electrocuted and/or sustain hand injuries working on switch gear	Lack of illumination at access panels Access restrictions limit sight lines and effective use of caplamps. Fixed lighting does not provide illumination inside switch panels Working in restricted workspace (inside panels)