Guideline for Underground Emergency Escape Systems And The Provision of Self Rescuers

MDG 1020

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Produced by
Mine Safety Operations Division
New South Wales
Department of Primary Industries

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FOREWORD

Clauses of the Coal Mines Regulations relating to MDG 1020 *Guideline for Underground Emergency Escape Systems and the Provision of Self Rescuers* are indicated in the References section of the Guideline. The Department of Mineral Resources document MDG 1020 *TR Technical Reference Material for Underground Emergency Escape Systems* provides technical reference material for the Guideline.

This is an Applied Guideline. Further information on the status of an Applied Guideline in the range of OHS instruments is available through the Department of Mineral Resources Legislation Update Number 2/2001. The range of instruments include:

- Acts of Parliament
- Regulations made under the Act
- Conditions of Exemption or Approval
- Standards (AS, ISO, IEC)
- Approved Codes of Practice (under the OHS Act)
- Applied Guidelines (under clause 14 of the Coal Mines (General) Regulation 1999)
- Published Guidelines
- Guidance Notes
- Technical Reference documents
- Safety Alerts

The principles stated in this document are intended as general guidelines only for the assistance of owners and managers in devising safety standards for the working of mines. Owners and managers should rely upon their own advice, skills and experience in applying safety standards to be observed in individual workplaces.

The State of New South Wales and its officers or agents including individual authors or editors will not be held liable for any loss or damage whatsoever (including liability for negligence and consequential losses) suffered by any person acting in reliance or purported reliance upon this Guideline.

The MDG1020 *Guideline for Underground Emergency Escape Systems and the Provision of Self Rescuers* was distributed to industry for consultation and comment through the Coal Safety Advisory Committee.

The Department of Mineral Resources has a review time set for each Guideline that it publishes. This can be brought forward if required. Input and comment from industry representatives will be much appreciated. The Feedback Sheet at the end of this document can be used to provide input and comment.

R Regan
Assistant Director Safety Operations

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DISCLAIMER

The compilation of information contained in this document relies upon material and data derived from a number of third party sources and is intended as a guide only in devising risk and safety management systems for the working of mines and is not designed to replace or be used instead of an appropriately designed safety management plan for each individual mine. Users should rely on their own advice, skills and experience in applying risk and safety management systems in individual workplaces.

Use of this document does not relieve the user (or a person on whose behalf it is used) of any obligation or duty that might arise under any legislation (including the Occupational Health & Safety Act 2000, any other Act containing requirements relating to mine safety and any regulations and rules under those Acts) covering the activities to which this document has been or is to be applied.

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Users should always verify historical material by making and relying upon their own separate inquiries prior to making any important decisions or taking any action on the basis of this information.

CONTENTS

Purpose and scope

The purpose of this guideline is to support:

- the development, implementation and assessment of underground emergency systems required by Regulation but confined to the escape or evacuation of persons affected by emergencies; and
- the providing of self rescuer units integral to those systems

Annexed to this guideline is a document MDG 1020 TR providing technical reference material that can be considered to benchmark Good Industry Practice for mitigating the risks associated with fires and explosions in underground coal mines at this time.

Good Industry Practice represents a standard of emergency escape management that is not necessarily the highest but is the most appropriate application of sound, goal setting design known to be practised in the industry at a particular time.

Escape strategies developed from this guideline are not intended to take the place of broader, comprehensive emergency planning for a mine. They should form a subset of the general Underground Emergency System for a mine.

The fundamental approach that underpins this guideline is that all mineworkers must be provided with the capability and resources to facilitate escape from their place of work to the surface.

Capability means:

- self rescuer apparatus fit for purpose
- an effective communications system
- an early warning system
- guidance systems / lifelines
- suitable escapeway paths providing unhindered passage
- a protocol for donning and changeover of self rescuers
- appropriate training

Note that

- Adherence to guidelines does not of itself assure compliance with the general Duty of Care
- Mine operators deviating from guidelines should document a risk assessment supporting the alternative arrangements

References

Legislation

- Occupational Health and Safety Act 2000, general duty of care
- Clause 102 (3) (b) of the Coal Mines (Underground) Regulation, 1999
- Clause 102 (4) (b), (c), (d), (e) of the Coal Mines (Underground) Regulation, 1999
- Clause 102 (5) of the Coal Mines (Underground) Regulation, 1999
- Clause 106 (1), (2), (3) of the Coal Mines (Underground) Regulation, 1999

Department of Mineral Resources publications

- MDG 1010 Risk Management Handbook
- MDG 1020TR Technical Reference Material for Underground Emergency Escape Systems and Provision of Self Rescuers; NSW Department of Mineral Resources
- MDG 3006 MRT 4 Code for Chemical Oxygen (KO_2) Self Contained Self Rescuers
- MDG 3006 MRT 7 Code for Maintaining, Monitoring and Testing the Performance of Escape Breathing Apparatus used in Underground Coal Mines

Other references

- Behavioural and Organisational Dimensions of Underground Mine Fires; US Dept. of Health and Human Services, NIOSH IC 9450 /2000
- ResQpacs-How to calculate safe travelling distances; COMRO South Africa Information Leaflet No.46 November 1989
- The Emergence of Leadership in a Crisis: A Study of Group Escapes From Fire in Underground Coal Mines - USBM, IC9385/ 1994
- An Overview of Research on Self-Contained Self-Rescuer Training; USBM Bulletin 695/ 1993

Emergency escape management system

General

Management systems for emergency escape should be integrated with the mine safety systems developed and implemented under the Coal Mines (Underground) Regulation, 1999.

Risk assessment methodology should be used to identify and quantify scenarios likely to trigger the need for emergency escape and to identify controls and barriers. Conduct of risk assessments and development of systems and procedures should be in consultation with employees and their representatives where appropriate. A Risk Assessment Protocol providing guidance in scope and format is included in MDG 1020 TR.

Procedures for evaluation and review of the entire emergency escape system should be developed as part of the emergency escape strategy.

Emergency procedures should be exercised at each mine on a systematic basis.

Regard should also be had to any relevant guidelines such as:

- MDG 3006 MRT 7 Code for Maintaining, Monitoring and Testing the Performance of Escape Breathing Apparatus used in Underground Coal Mines
- MDG 3006 MRT 4 Code for Chemical Oxygen (KO_2) Self Contained Self Rescuers

Record keeping and documentation

Record keeping should be integrated with the Mine Safety Management Plan (MSMP) record system. Records should accurately reflect current serviceability of equipment, competency of persons and responsibilities that are associated with the emergency escape system, and the outcomes from simulation exercises.

Training

The Emergency Escape System should recognise that training is a major factor in successful escape.

Specific training needs and competencies associated with the emergency escape system should be identified and appropriate training modules developed for all persons relevant to the Emergency Escape System.

All persons should be appropriately trained and competent to make use of the emergency escape systems provided at the mine as applies to them. Where there is a need for a 'competent person', the competencies should be defined and a list of persons who have those competencies created and kept up to date.

All employees should receive refresher training at scheduled/ regular intervals. Training and skills should be documented on personnel files.

Visitors and non permanent employees should receive suitable induction training with regards to the relevant elements in the Emergency Escape System.

Monitoring, systems audit and review

The underground emergency escape system must include an auditing regime to ensure all required facilities are present and in a state of readiness. The emergency escape system should be part of the continuous improvement process for mine management systems. This includes action to:

- monitor record-keeping
- analyse results, both routinely and after simulation exercises, special occurrences or problems
- feed results of the analysis back into future planning and operations

Simulation exercises

The mine should set up a schedule of practical exercises that systematically tests the effectiveness of the emergency escape systems for the mine. The exercises should include a debrief of participants and recording of outcomes.

Risk identification and assessment

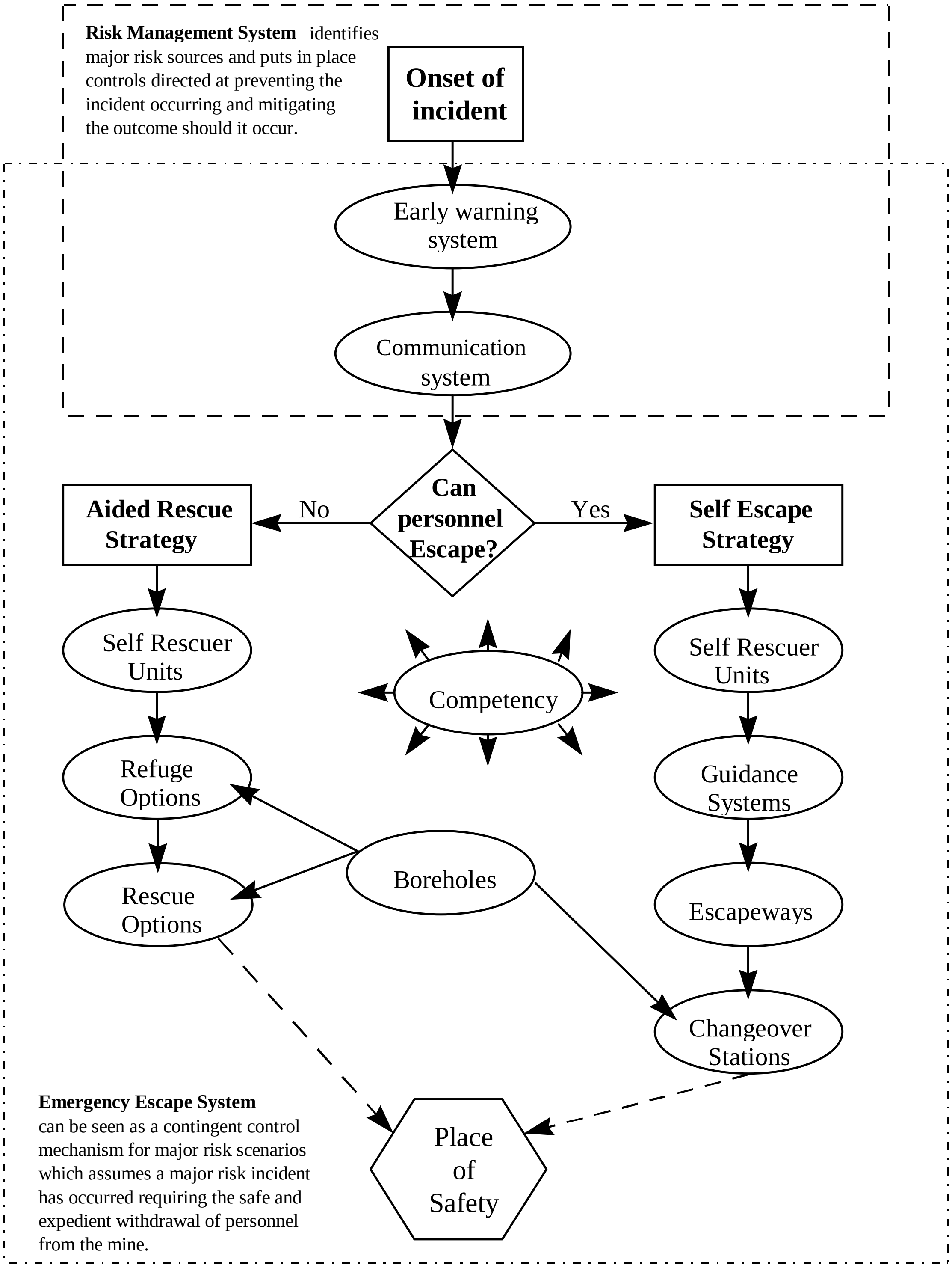
The following pages list key system component outcomes, associated risks and main risk considerations. The Figure on page 4 illustrates emergency escape elements.

The guidance material annexed to this document (MDG 1020 TR) tables the key system components and issues to be considered with examples of Good Industry Practice used to address them.

These lists and tables are not exhaustive – there may always be other hazards, including site-specific hazards which must be identified, assessed and controlled, as well as alternative means of controlling the hazards.

For more information on how to conduct a risk assessment refer to MDG 1010 Risk Management Handbook.

FLOWCHART OF EMERGENCY ESCAPE ELEMENTS



Emergency escape system - elements and considerations

Early warning

Required outcome

Conditions of potential or imminent emergency requiring escape from a mine or any part of a mine are identified at an early stage. The appropriate alarm is communicated to persons who may be endangered so as to expedite their escape.

Main risks

- monitoring system does not survive event
- monitoring system is not reliable and/or not accurate
- alarm system fails/ damaged in event

Main risk considerations

- monitoring system adequately designed, maintained and calibrated
- detection points positioned and alarms initiated in appropriate locations
- alarm settings linked to a graded response plan
- early warning systems and associated decision making protocols are included in competency based training scheme

Communication

Required outcome

Effective communication to all persons required to work or travel underground of the paths of egress from each part of the mine. An adequate communications system makes possible the co-ordination of all other systems and provides the key to early notification of an emergency event and coordination of response.

Main risks

- all underground personnel not notified of the need to escape and details of the incident/ safest route of escape
- escaping persons cannot locate or use communication system
- personnel do not respond to the incident control centre
- communication systems do not survive the incident
- communication system is not reliable
- communication transmissions interfere with gas detection equipment

Main risk considerations

- management plans which direct how to communicate, who communicates and what is communicated in an emergency
- communication system operates in the absence of underground power
- breathing apparatus provides wearer ability for verbal communication or a non-verbal communication protocol has been developed
- there is a testing regime for the communication system
- contingency plans are in place should the communication system fail

Self rescuer apparatus

Required outcome

Persons underground are provided with respiratory protection apparatus to allow safe egress from the mine through any irrespirable or irritant atmospheres that may be encountered.

Main risks

- the limitations of the selected self rescuer apparatus are not understood
- the self rescuer apparatus does not suit the purpose for which it will be used
- cache spacings do not allow an escaping person to reach and don a new unit before the unit they are wearing expires
- caches do not contain sufficient numbers of units
- underground personnel are not medically fit to wear the self rescuer units
- the integrity of the self rescuer apparatus deteriorates and no longer affords any/ sufficient protection
- where units are stored on transports degradation due to vibration has not been addressed

Main risk considerations

- self rescuer apparatus is approved for underground use
- cached units are stored in an easily accessible, appropriately designed and located container
- the use of the selected self rescuer apparatus is supported by a competency based training scheme given by accredited trainers, and it includes unit changeover in an irrespirable atmosphere
- there is a system which caters for the issue/return of person-worn units and inspections/ maintenance
- selected self rescuer apparatus are serviced by accredited providers

- there is a monitoring program for unit integrity over the service life of the units
- there is a record of units on site, their batch number, their in-service details and maintenance history

Guidance systems / lifelines

Required outcome

A system is provided to aid personnel in their escape through conditions of reduced visibility. Paths of egress are marked so that persons who are not familiar with a route can safely travel it in conditions of poor visibility.

Main risks

- persons cannot find the guidance system
- locations of caches/ changeover stations/ refuges cannot be found in conditions of poor visibility
- guidance system does not survive the incident
- guidance system does not indicate the direction of travel in conditions of poor visibility

Main risk considerations

- guidance system needs to be readily accessible
- clearly identifiable access points to escapeways
- there is provided easy access to, or a documented means of reaching, the start of the guidance system
- the guidance system provides continuous directions to a place of safety, such as provided by lifelines fitted with directional cones
- the guidance system leads the escaping person along a path unhindered by obstacles
- the guidance system is included in the competency based training scheme

Escapeways & transport aided escape

Required outcome

At least two escape routes are provided from each part of the mine to the surface so that in the event one becomes impassable another is always available for travel. There are sufficient types and numbers of transport or alternate escape means, in combination with escape equipment, to allow the safe evacuation of persons.

Main risks

- escapeways not trafficable
- fire or explosion destroys stoppings between segregated escapeways
- fire occurs on equipment located in escapeway
- the environmental conditions during/after the incident preclude the use of transport vehicle
- available transport does not cater for the maximum number of persons in the area
- transports used as part of escape strategy collide in poor visibility conditions

Main risk considerations

- there is a primary (intake) and alternate escapeway nominated from all districts to the surface or a place of safety
- primary escapeway maintained in good trafficable condition
- escapeways are segregated by substantial, fire resistant stoppings
- fire sources in escapeways have been identified and controlled
- where transports form part of escape strategy, they cater for the maximum number of persons likely to be in the area
- where transports form part of escape strategy, a guidance system is implemented together with an effective signalling system or control mechanism to address the hazard of collision
- a competency based training scheme addresses choice of escape routes, access to escapeways, conditions in escapeways and location of equipment within escapeways
- where new hazards are introduced to the escapeway a reassessment of the escape strategy is triggered

Change-over stations (COS)

Required outcome

Places along escapeways providing safe storage/caches of self rescuer units where efficient change over of self rescuers is facilitated. At least the first change-over station from a production unit should facilitate safe assembly of escaping persons and communication.

Main risks

- COS not located within the duration of supplied self rescuer apparatus
- unsuccessful change over of self rescuer apparatus in irrespirable atmosphere
- damage to COS prevents escaping persons acquiring replacement self rescuer apparatus
- system supplying air to Respirable Air Change-Over Station (RACOS) does not survive the incident
- ingress of toxic gases into RACOS
- RACOS does not allow access for stretcher
- RACOS does not cater for the maximum number of persons likely to use it

Main risk considerations

- COS are located and constructed such that they will resist damage during normal operations and emergency use
- where RACOS are supplied, there is a maintenance/inspection program
- monitoring device is available to indicate air inside RACOS is safe
- where RACOS are provided the competency based training scheme includes access to RACOS and the requirements of their use
- all training should assume an irrespirable atmosphere for self rescuer apparatus change over

Refuge options

Required outcome

Pre-planned rescue strategies and/ or facilities are provided for scenarios where personnel cannot self escape. These may include Refuge Chambers (RC).

Main risks

- persons opt to remain in RC rather than continuing with self escape strategy
- air supply exhausted in RC before escape effected
- RC air supply system does not survive the incident
- ingress of toxic gases into RC
- RC not located within the duration of supplied self rescuer apparatus
- RC does not allow access for stretcher entry
- RC does not cater for the maximum number of persons likely to use them
- Surface control room does not know persons are sheltering in RC

Main risk considerations

- where refuge chambers are provided there is a pre-planned strategy to rescue the occupants
- RC are located and constructed such that they will resist damage during normal operations and emergency use
- where RC are supplied, there is a maintenance/inspection program
- monitoring device is available to indicate air inside RC is safe
- occupants of RC have means of communication to surface
- where RC are provided the competency based training scheme includes access to RC and the requirements of their use

Boreholes

Required outcome

Role (potential) in communications and air supply to refuge stations and/or respirable air change-over stations, and in the recovery of personnel from underground workings.

Main risks

- a suitable drill rig (and escape equipment if required) is not available within an appropriate timeframe
- drilling takes longer than planned
- surface and underground sites are not compatible
- access to surface is not available or suitable for drill site

Main risk considerations

- a suitable rig is available within appropriate timeframe or borehole is pre drilled
- where a borehole is part of planned rescue strategy the surface location is available, secure, surveyed, cleared, consolidated and provided with all weather access
- where a borehole is part of planned rescue strategy the underground target site is surveyed, suitably supported, cleared and marked
- where a borehole is part of planned rescue strategy the depth, stratigraphy, hole stability and drillability should be known

Competency

Required outcome

A system is in place to ensure all persons going underground and all personnel with duties under the emergency escape system are competent in their roles.

Main risks

- all persons including employees, contractors and visitors do not receive induction and continuing training appropriate to risk, their role and responsibility
- appropriate training is not conducted before implementation of significant changes to the emergency escape system
- persons are unfamiliar with escape route alternatives/ cache locations etc
- incident occurs when a person/s with specific responsibility under emergency escape system is uncontactable

Main risk considerations

- competency based training scheme (CBTS) includes all relevant aspects for all underground personnel
- CBTS includes additional modules for supervisors
- CBTS includes personnel (and their alternates) who have specific roles in the emergency escape system
- CBTS includes exercises of a practical and desk-top nature
- CBTS includes exercises which include external emergency services
- CBTS covers visitors and contractors
- trainers are competent to provide the necessary training

Feedback sheet

Your comment on this Guideline will be very helpful in reviewing and improving the document.

Please copy and complete the Feedback Sheet and return it to:

Steve Stewart
Mine Safety and Environment
NSW Department of Mineral Resources
PO Box 536
St Leonards NSW 1590
Fax: (02) 99018584

How did you use, or intend to use, this Guideline?

What do you find most useful about the Guideline?

What do you find least useful?

Do you have any suggested changes to the Guideline?

Thank you for completing and returning this Feedback Sheet

MDG 1020TR

TECHNICAL REFERENCE MATERIAL

FOR

UNDERGROUND EMERGENCY ESCAPE SYSTEMS

AND

PROVISION OF SELF RESCUERS

Prepared for:	Chief Inspector of Coal Mines Department of Mineral Resources
Date completed:	19 April, 1999

PREFACE

This report contains fundamental input into any risk assessment process associated with the development or evaluation of an escape strategy and as such a copy should be provided to each member of a mine site risk assessment team.

The material covers the major elements of an emergency escape system identified by New South Wales and Queensland industry working groups and the results of a study of overseas escape strategies.

It is intended that the material provided be used to support risk reviews to be undertaken at each mine, ensuring emergency escape systems are tailored to a mine's particular circumstances.

The escalation of an emergency from the onset of an incident through to escape or rescue is depicted by flowchart in Figure 1, MDG 1020. A critical decision point is reached where personnel must decide if escape is possible. This decision may be dictated by the event, injuries to personnel or the physical location of the work area. If escape is not possible, then personnel would need to seek refuge and await a subsequent rescue effort. Important elements to consider are shown in the flowchart in an oval-shaped symbol and include:

1. **Early Warning -** identifying the problem early, through monitoring, so that appropriate actions and communications can be expedited.

2. **Communication -** broadcasting an evacuation order along with information relevant to the incident.

3. **Self Rescuer Apparatus -** apparatus which allows escape through irrespirable and/ or toxic atmospheres.

4. **Guidance Systems / Lifelines -** equipment to aid personnel in their escape through atmospheres which potentially allow poor visibility.

5. **Escapeways -** escape routes from all working places to the surface.

6. **Change-Over Stations -** stations where cached self rescuer units are stored along the escapeways and self rescue apparatus donned/ changed over.

7. **Refuge Options -** facilities provided where escape is not possible.

8. **Rescue Options -** pre-planned rescue strategies for scenarios where personnel cannot escape.

9. **Boreholes -** have a potential role in communications and air supply to refuge stations and/or respirable air changeover stations, and in the recovery of personnel from underground workings.

10. **Competency -** an essential part of any system dealing with people is the training and ongoing competency assessment of those involved.

The principle objectives of this report are to provide:

- examples of good industry practice;
- issues that should be considered in developing and implementing or assessing underground emergency systems; and
- an identification of various technical and management solutions, their merits and deficiencies.

Issues to be considered with each of these emergency escape elements are identified and guidance material provided, in section 3 of this document. Observations on current international best practice are included as are references to relevant documents arising from other work.

The element “Rescue Options” is not covered and readers, when assessing rescue contingencies, should at least refer to the work of Task Group 4 in Queensland and the Mines Rescue Board of NSW’ “Emergency Preparedness and Mines Rescue Guidelines”.

WORKING GROUP MEMBERS

The NSW Chief Inspector of Coal Mines set up a working group to develop this guidance material.

The working group had the following membership:

Mr W Barraclough
Process Safety Manager - Collieries Division, BHP Coal

Mr R Bancroft
Senior Inspector of Coal Mines - Dept. of Minerals and Energy Qld

Mr G Dwyer
District Check Inspector - United Mineworkers' Union

Mr P Eade
Manager Mining and Geo-technology - Collieries Division, BHP Coal

Mr G Fawcett
Manager Mine Safety Unit - Department of Mineral Resources

Mr G Macdonald (Chairman)
Senior Inspector of Coal Mines - Department of Mineral Resources

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Manager Coal Mines Technical Services - Mines Rescue Service of NSW

Mr F O'Connor
Under-Manager Appin Colliery

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1.0 RELATIONSHIP WITH REGULATIONS

A Regulation to the NSW Coal Mines Regulation Act requires a mine manager to develop and implement an ‘underground emergency system’ and specifies minimum requirements for an emergency system. In developing and implementing such a system regard must be had to any relevant guidance material published by the Chief Inspector.

In addition, a manager must provide adequately maintained approved types of self rescuers. The provision and maintenance of these items must also be undertaken with regard to published guidance material.

These requirements give rise to a need for the following:

- guidance material for underground emergency systems;
- a standard against which oxygen self rescuers may be certified as being of an approved type; and
- guidance material for the provision and maintenance of self rescuers.

A separate document, MDG 3004 MRT 4 “Guideline for Chemical Oxygen (KO_2) Self Contained Self Rescuers” has been prepared. This is the standard against which these rescuers may be evaluated to determine fitness for purpose, for approval certification and also the suitability of this type of apparatus for inclusion into an escape strategy.

The guidance material provided herein does not address the full scope of the draft legislation for emergency systems. It addresses those systems relating to emergency escape from a fire or explosion where underground personnel are required to escape through potentially irrespirable atmospheres or await rescue. It addresses the provision and maintenance of self rescuers.

The Queensland Regulations require all mines to develop and implement a ‘Hazard Management Plan for Emergency Evacuations from Underground Mines’. The plan must be developed in accordance with an approved standard. A manager must provide adequately maintained approved types of self rescuers.

2.0 RISK ASSESSMENT PROTOCOL

This report recommends that the mine's escape strategy be based upon a risk assessment. This element provides guidance in the scope and format of such a risk assessment relating to emergency escape where underground personnel are required to escape through potentially irrespirable atmospheres or await rescue. This element should be read in conjunction with MDG 1010 "Risk Management Handbook for the Mining Industry" published in May 1997 by the NSW Department of Mineral Resources.

Category	Issues to be considered	Notes
Essential requirements	All risk assessments are to be consistent with the requirements of MDG 1010.	
Draft escape plan	Utilising the guidance material contained within this document an escape plan can be developed which nominates specific escapeways, cache locations, numbers of units per cache, etc.	
Key risks for the mine	Each individual mine needs to assess their operations to identify their key risk exposures.	Key risk exposures are those types of incidents which may be low in probability but, should they occur, would have a catastrophic consequence. For an example, a small underground coal mine may assess their operations and identify the key risk exposures as fire, explosion, fall of roof and major transport collision.
Scenarios requiring escape through potentially polluted atmospheres, or possible entrapment in potentially polluted atmospheres.	For the purposes of the risk assessment required by this document, scenarios requiring escape or entrapment under potentially polluted atmospheres need to be identified from the list of the mine's key risk exposures.	Taking the above example a step further, this process may identify fire, explosion and fall of roof (where possibility of entrapment in an unventilated environment) as relevant scenarios. A major transport collision is discounted from this risk assessment as it would not result in the need for personnel to escape through polluted atmospheres. This does not negate the need for transport collisions to be assessed in a separate emergency preparedness exercise.

Risk Assessment Protocol

Categorise risk scenarios	A range of generic scenarios need to be developed for each relevant key risk. Special case scenarios should also be identified.	Taking the fire risk in the above example, the assessment group may determine that dividing the mine into the following generic sections is appropriate: • a fire at pit bottom • a fire in the main trunk roadways • a fire in the longwall entry • a fire in a gateroad panel In addition, the group may identify a fire in the underground vehicle servicing station as a special case for consideration due to its location and the quantity of fuel available to feed the fire.
Risk identification on draft plan	A risk (or potential loss) identification process is undertaken utilising the draft escape plan and the generic and special case scenarios generated above.	The "Issues" identified in these guidance notes can best be used in this risk identification process as a checklist which will assist in a comprehensive assessment of the draft escape plan. A shortform checklist appears in MDG 1020 .
Rating of identified risks	Each identified risk or loss potential is to be rated for probability and consequence.	Many risk rating matrices are available which will serve this purpose. MDG 1010 provides a simple 3x3 matrix for consideration.
Assessment of controls/barriers	Existing controls/barriers for each identified risk or loss potential is to be documented and assessed for adequacy. Improvement actions are generated.	Improvement actions should be prioritised according to the risk rating completed above.
Action plan review	A realistic review of improvement actions is required to divide actions into two further categories: 1. Those actions required prior to commencement of the new escape strategy; 2. Those actions which can be made over time to enhance the strategy.	This differentiation is required to accommodate actions such as segregated intakes which, in a well established mine, may take a significant amount of time to achieve. Such an improvement action should not delay implementation of the escape strategy where other controls/barriers are in place. The over-riding constraint in this differentiation is the safety of personnel escaping from the mine, ie whether the action is <u>necessary</u> for the safety of personnel or an enhancement which will further improve the system.

3.0 GUIDANCE MATERIAL FOR EMERGENCY ESCAPE SYSTEMS

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: EARLY WARNING

The role of an early warning system is to sense the first signs of fire or explosion and communicate an alarm so that evacuation of the mine or part can take place safely, through reasonably smoke free escapeways and control measures can be taken at the earliest time.

Category	Issues to be considered	Notes
Monitoring	Early warning implies early detection.	Early warning signs of fire include: change in ambient odour; visible smoke; smoke sensors alarm; CO sensors alarm; and finally heat sensors alarm.
	CO and increasingly smoke sensing systems offer considerable potential for earlier and more reliable fire detection than do other available systems.	The CO detector is still by far the most common detector for fire detection in U.S., South African and Australian coal mines. The use of smoke detectors as part of atmospheric monitoring systems is reported as increasing but their use is not wide. Tests conducted by MSHA indicate that smoke sensors may provide earlier warning than CO detectors in some circumstances. Thermal and optical systems, because they require a high density of installation, are more suitable for protecting localised, high risk areas or for protecting underground equipment when they can be placed close to an identified hazard. In dense smoke their detection ability is reduced.

Early Warning

Category	Issues to be considered	Notes
Monitoring cont.	The type of sensor is not the only factor influencing alarm response time.	The time for a detector to sense the presence of a fire and provide an alarm is a function of the type of sensor, the nature of the fire products and their quantity and distribution, the fire size, ventilation velocity, airway dimensions and the spacing between sensors. Factors that may serve to confuse a detection system include the use of diesel equipment and ventilation flows that intersect and mix, reducing combustion product concentrations.
Survivability	An advantage of an early warning system would be capability to provide ongoing information during the emergency.	If the system fails upon the incident occurring then post incident response and decision making is impaired.
Control Systems	An early warning control system should provide sufficient data to allow the safest route of escape to be determined and communicated to all persons in the mine.	A control system must be established to receive and analyse data on the underground environment. The system must include decision making protocols and enable control to be maintained and action to be co-ordinated during an emergency. It is essential to be able to contact all groups of workers as quickly as possible and give precise evacuation instructions. Computer generated emergency alert systems are available where recorded messages can be transmitted to localities on an at risk basis. The Reumaux (HBL) mine in France utilises such a system with a maximum of 10 localities alerted at one time. An alert immediately triggers the escape procedure. Computer systems should be capable of generating time-view graphs demonstrating trends.

Early Warning

Category	Issues to be considered	Notes
Trigger levels	Systems which have the ability to determine and advise when to commence escape and when to don self rescuers may be important.	Trigger points need to be established on a mine site basis taking into account the background levels and history of the seam and the mine. While use of 'rule of thumb' figures as trigger points is cautioned against both U.S. and S.A. Governments have legislated alert / alarm levels for CO. Adoption of a fixed CO level, while useful as a trigger for evacuation response, is not indicative of the general level of hazard. A CO monitoring system capable of reporting CO make and a computing system programmed to properly recognise normal and abnormal increases is preferred.
Warning systems	Detection systems with both local and remote alarm capability should be incorporated into early warning systems.	Detection systems may provide local or remote alarm and be designed for fixed installation, mounting on mobile equipment, carrying on the body, or involve discrete sampling and laboratory analysis. With fixed units there is the capability of transmitting data in real time to a surface computerised control centre where data from several sensors can be analysed and an early warning message generated on a structured, prioritised and best option basis. Also available are networked gas monitoring systems not dependent on a master computer or distributed field controllers for monitoring and control functions. Fixed units may also operate in isolation providing local alarm only or gas samples may be transported to the surface for analysis, with data then transmitted to the control centre. Tube bundle sampling with surface analysis provides the capability of monitoring trends and therefore the ability to detect the early onset of spontaneous combustion.

Early Warning

Category	Issues to be considered	Notes
Warning systems cont.		Hand held and body worn CO monitors provide local warning only and rely on personal telephone or radio communication to extend warning to other areas of the mine. Multi gas detectors with data logging capabilities and ability to automatically compensate sensor readings for changes in atmospheric pressure are available.
	Alert / alarm devices	Sirens, horns and strobes located in workplaces and the surface control room are commonly used and may also serve to indicate the level of alarm and the escape route. One mine in the U.S. with 1ppm return air ambient CO has the following alert program. At 3.5ppm a strobe warning commences in surface control room; at 6ppm the section strobe (located at boot-end or BLS) activates; at 11ppm section and control room horns commence sounding.
		The telephone communication system may incorporate loudspeakers such as a DAC's system located in conveyor belt roads.
		Electronic systems triggered by environmental sensors or from the control room giving audible and visual signals in a cyclic routine. Advice from South Africa is that maintenance and replacement problems have been experienced with these units. The problems need to be addressed. The sound signals may cause disorientation in dense smoke, particularly when the sound generating units are installed well above head height.
		The stench gas warning system operates by releasing an odoriferous chemical into the mine's ventilation / and or compressed air stream. Evacuation according to a prearranged evacuation plan is to commence immediately on detection of the odour. The system relies on the air current carrying the odour quickly to all working places in a mine.

Early Warning

Category	Issues to be considered	Notes
Warning systems cont.		The stench warning system is not considered a practical option by South African coal miners due to the extensive nature of multi-heading coal mine workings. Disruption/ short circuiting of the ventilation system may occur following an explosion or fire. Transit times for stench in compressed air lines can be unacceptably long where compressed air usage is minimal.
	Computer systems can generate alarms and warning messages simultaneously to multiple localities.	Computerised smart systems capable automatically analysing data and generating telephone warning messages are available. Also the capability of remote interrogation of these units is available. HBL mines in France each have installed a dedicated emergency telephone network which has the capability of continuously broadcasting pre-recorded warning messages or instructions appropriate to the circumstances, via a simple selection procedure on a microcomputer in the control room.
	Operational matters	False alarms, calibration, testing and general detector reliability, together with the ability to verify receipt of an alarm are all issues that must be considered in assessing monitoring and alarm systems. A security system should ensure that alarms are only acknowledged and/ or altered by an authorised person. There is a need to space sensors correctly along roadways.
	Some sensor heads can be corrupted if exposed to high concentrations of a gas.	Decision making is impaired.

Early Warning

Category	Issues to be considered	Notes
Warning systems cont	• False alarms - CO detectors	Electro-chemical CO detectors are generally reliable in operation but can give false readings in the presence of gasses such as NO_2, NO, H_2S and H_2. A major reason for nuisance alarms with CO detectors is diesel exhaust. To compensate for elevated background CO levels due to diesels, mine operators may: • increase the threshold alarm level of their sensors, but in so doing negate sensor value by decreasing the amount of time that miners have to escape; • utilise a time delay to cater for CO spikes; • administratively limit the number of diesel engines operating in a given area.
		MSHA report they have been testing diesel discriminating CO detectors for some years and anticipate they will approve one soon for use in coal mines. Reduction of false alarms with this unit is reported to be as much as 80%.
	• False alarms - Smoke detectors	Submicron particulate detectors can be effected by dust and moisture and early models had a history of malfunction in the underground coal mine environment. The type of detector has a bearing on the sensitivity to nuisance alarm. MSHA have approved several smoke detectors for use in US coal mines and there is a South African unit that has been reported as giving excellent results. Suitability for Aust. coal mines should be investigated.
	• Calibration	The system needs to be calibrated, maintained and audited in accordance with AS 2290.3 -1990 'Maintenance of Gas Detecting and Monitoring Equipment'. Calibration and maintenance should be simple and not require excessive time and labour. Sensor readings displayed at the surface control room need to be periodically checked against actual sensor output.

Early Warning

Category	Issues to be considered	Notes
	• Detector reliability	Detector systems need to be durable enough to withstand the mine environment over long periods of time while maintaining reliability.
	• Testing	It is recommended that alarms be tested daily where reasonably possible. Systems powered from the normal underground power supply should have battery back-up where practicable. Alternatively a dedicated power line from the surface should be considered.
	• Verification	Acknowledgement of warning messages assists with the overall control of rescue operations.
People matters	Decision making protocols are essential for avoiding panic and making the right decisions.	Where any system involves persons there must be a written decision making protocol. Protocols must be prepared for control room personnel that clearly define actions required on sensors alarming and persons responsible for taking action suitably trained.
	Training is a major issue in successful escape as is the need for leadership in a crisis situation.	The need for leadership in a crisis should not be overlooked. A US Bureau of Mines study into “The Emergence Of Leadership In A Crisis”, IC/935 considered that training for response to mine emergencies should consider the likely human behaviour tendencies and the importance of having in each work crew at least one person who can and would lead the group in the event of an emergency.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: COMMUNICATION SYSTEMS

An adequate communications system makes possible the co-ordination of all other systems and provides the key to early notification of an emergency event and co-ordination of response.

Category	Issues to be considered	Notes
Management Control Plans	Formal management plans should be developed to support efficient use of communication system	A control plan should identify the range of possible incidents, early warning trigger levels and incident response actions. A control plan should cover how to communicate, who communicates messages, what information or instructions are to be given and include a hierarchy of accountabilities.
System capability	Systems should provide: • immediate notification to persons in all areas of the mine of the need to evacuate • incident details and best evacuation route details to all underground persons • two way communication	Principle communication systems currently available include: • telephone • radio – Leaky Feeder (LF) coaxial cable systems – Medium Frequency (MF) inductive systems – Ultra Low Frequency (ULF) Through-the-Earth systems (not 2-way) See also element: Early Warning.

Communications Systems

Category	Issues to be considered	Notes
System attributes	Robustness	Systems need to be designed as far as practicable to survive an incident. Communication devices (radio, phone, pager, keyboard) should be of solid construction. The mode of transmission needs to be protected from the effects of fire/explosion or have sufficient redundancy to remain operable post incident. Access via a boreholes, armoured aerials and duplicated aerials are all possible means of ensuring system survives incident.
	Reliability	System needs to maintain service uptime under normal use and thus engender confidence that system will be available for emergency use. Supplement suppliers data with actual field experience.
	Ability to operate in the absence of normal underground electrical supply	System down powered or has battery back-up of sufficient duration.
	Ability to aid in tracking personnel movements post incident or locating trapped employees is beneficial.	Moura #2 task group saw this as an advantage in incident response management. Transponder cards can be inbuilt in SCSR cases or cap lamps. This system may allow the automatic registration of persons passing a gate and needs to be I.S. or explosion protected.
	Ability to support video and data transmission to enhance emergency response	Moura #2 task group saw this as an advantage in incident response management.

Communications Systems

Category	Issues to be considered	Notes
	Ability to communicate while wearing escape apparatus	Limited ability to communicate verbally while wearing a self rescuer. Ability to communicate under escape apparatus is preferable however performance of current mechanical devices is poor.
	Ergonomic design of any person-worn units	Person-worn units designed for comfort and ease of use under stressful conditions.
System survival capabilities	Telephone transmission systems may not operate following an explosion or fire.	The telephone system is the most widely used communication system for providing warning in an emergency. The risk of failure of this system following a fire or explosion should be considered in developing early warning and post incident communications systems. Dedicated emergency telephone networks and perhaps utilisation of borehole/s should be considered.
	Electromagnetic transmission systems have varying capabilities and only the through-the-earth system may operate following an explosion	Leaky Feeder systems operate in the HF or VHF range and require a ‘leaky coaxial cable’ to be extended wherever communications is required. Modified relatively cheap walkie-talkie type radio handsets are used to receive and transmit radio signals. The cost of cable is high and skilled technicians are needed to maintain the system.
		MF systems rely on continuous or semicontinuous metallic conductors being present to transmit signals through the mine. The MF transceivers inductively couple signals onto these conductors and receive radio signals from them. The transceivers need to be in the line of sight of any part of the conductor system. All persons in the mine may not be in contact range. MF transceivers are more expensive than the leaky feeder handsets. ULF systems such as PED utilise the transmission of electromagnetic signals through mine rock to underground workings where miners equipped with radio pagers are made aware of the emergency. The pagers may be mounted in and powered by a cap lamp battery and the message received displayed on a back-lit liquid crystal display.

Communications Systems

Category	Issues to be considered	Notes
		The PED system is considered to be the best system for getting an early warning to men underground but with no current provision for acknowledging receipt of message. Due to the requirement for a long surface loop antenna, surface access issues such as private ownership and rugged terrain may need to be considered. No coal mine in the U.S. or S.A. were reported to be using this system but some are considering installation. Qld have initiated research into a two-way ground induction system
Stray signal effects	Compliance with electrical detonation of explosives criteria	Some radio frequencies can act as an initiator of electrical detonation
Testing/training	A testing regime is required to ensure system performs adequately over time and people are competent in its use.	Supplier information can be a guide. Competency based assessment criteria should be used on an ongoing basis.
Interference with multi-gas detection equipment	Communication transmission may interfere with accuracy of multi-gas detection devices	Some devices can interfere with the accuracy of multi-gas detection devices. Suppliers and relevant research papers should be consulted.
Contingency	Avenues available when mine communication systems fail.	Seismic systems could possibly be used to detect and locate the source of seismic vibrations generated by underground persons pounding on mine surfaces. A seismic system is maintained by the MSHA Mine Emergency Response Team for use in locating trapped miners. The concept would have to be proved for use in our geological environment and for deep mines.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: SELF RESCUER APPARATUS

The role of a self rescuer is to provide persons underground with respiratory protection in the event of an emergency that impacts on air quality assisting escape to a place of safety or to where another self rescuer is provided.

Category	Issues to be considered	Notes
Type of Apparatus	Selection of the appropriate type or mix of types to ensure that all person's underground have the means available for self escape in the event of an emergency.	Types are identified in the Classification of Self Rescuer Apparatus, refer Section 4.0. Each type of self rescuer has specific advantages & disadvantages. These need to be critically examined when designing an escape strategy with the intention to select the most appropriate apparatus for the hazard(s) under consideration and provide the most effective deployment of apparatus.
Selection Criteria	Elements for Comparison of Self Rescuer Apparatus	Consideration to be given to the following elements: • preference should be for apparatus that has a self starting mechanism for an initial supply of oxygen. It is recognised that some manufacturer's utilise fast reacting chemicals & don't incorporate a self starter; • weight; • ease of donning • level of protection; • size & ergonomics; • availability of training models; • apparatus includes goggles. • robustness of the case • distribution of the weight from the waist to the shoulders. Note: Change over units (cache units) should have self starters.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
	Rated duration	The operating time accepted by the approving authority as appropriate for the apparatus to provide respiratory protection This is based on compliance with a specified standard, where an assessment is made using a breathing simulator under controlled conditions. This provides a baseline for comparison of apparatus and to monitor in service performance to detect deterioration.
	Communication	Where the self rescuer apparatus does not have built in a means of enabling communication then the mine must develop non verbal protocols for communication between escaping persons. This must be included in the training procedures.
	Apparatus selected for use by mines must have approval/acceptance by appropriate agencies.	The supplier must be able to demonstrate that the apparatus complies with standard(s) acceptable to the statutory authority.
Factors influencing performance	Effect of personal related factors on duration of chemical oxygen self rescuers	1. Body weight - most important factor that influencing oxygen consumption. It is almost impossible for persons >100kg to achieve rated duration, even at sub-maximal exertion. 2. Age - mechanical disadvantage for older people. Normally they use more energy & hence more oxygen to complete the same workload as a younger person. 3. Fitness - fitter people require less oxygen, therefore at maximal exertion they would achieve longer duration than unfit persons. However at sub-maximal exertion it appears that oxygen is more likely to be lost through the relief valve. This is subject to other factors such as the rate of reaction of the chemicals.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
		4. Anxiety - an anxious person will have an increased pulse rate and rapid shallow breathing. The increased blood flow produces metabolites & sweat. This does not consume oxygen in the blood. Rapid shallow breathing does not produce an excess of oxygen as the breath is drier than normal. 5. Heat & Humidity - people who work in hot & humid atmospheres will suffer an increase in pulse rate. This is the body's attempt to lose heat as blood is pumped to the skin. This activity does not consume oxygen. Australian ACARP funded research and South African research have found that based on current industry profile (weight, age, fitness) 95 percentile would achieve at least 60% of the rated duration. US Research into the utilisation of available oxygen has found that maximum efficiency is achieved when exertion is sub-maximal or controlled. Over exertion was found to lead to poor utilisation of the oxygen generating chemicals and under exertion to oxygen wastage through the relief valve.
	Factors impacting on escape distance when using chemical oxygen self rescuers.	One of the central aspects to the development of an effective escape strategy is to have a well conceived basis for determining the achievable travelling distances for each self rescuer apparatus to be used at the mine. This needs to take into account all conditions that may be encountered. As part of the mine site risk assessment process a trial to determine realistic travelling distances should be undertaken. The assessment needs to consider both the terrain of the mine and ability of those underground. An assessment approach developed by CSIR Miningtek is used by South African mines. Work has also been done by MSHA in this area . There is a need to keep reassessing and updating as the situation changes or plan for the worst case.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
		South African research and experience has found that: • in good conditions (good visibility & being able to travel standing upright) the following applies: 60 minute apparatus an average person can travel 2.5 km 30 minute apparatus an average person can travel 1.25 km 95 percentile (effects of body weight, fitness, age) can travel ~ 1.5 km for 60 minute apparatus ~ 0.75 km for 30 minute apparatus • poor visibility reduces distance travelled to 60% of that travelled in good visibility. Therefore 95 percentile will achieve 1 km with a 60 minute apparatus and 500 m with a 30 minute apparatus. The South African coal mining industry uses 30 minute chemical oxygen apparatus in combination with refuge bays. US require 60 minutes apparatus to be belt worn or located 25 feet from person. In the latter case the person must have a belt worn Filter Self Rescuer (FSR). Approx. 50% of US coal mines use chemical oxygen apparatus. Germany use long duration FSR's, France have a system using 30 minute belt worn chemical oxygen apparatus, refuge chambers and cached long duration chemical oxygen apparatus.
Cached Apparatus	Location Type & duration of apparatus to be stored	Cached apparatus should be located within the distance achievable by 95 percentile of the workforce using belt worn apparatus. In South Africa it has been found necessary to have a refuge bay within 500m of the face. Further refuge bays are 1-1.5 km outbye. This took into account poor visibility scenario. If the integrity of the ventilation circuit is high then the caching of FSRs may be an option. Compressed air suffers from a poor weight to duration ratio Compressed oxygen the comment for chemical oxygen applies. Compressed oxygen & compressed air units have a high maintenance & testing requirements compared to chemical oxygen.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
	Distance to next cache Construction of cache Identification of cache Number of units to be cached	Refer to achievable travelling distances above. The further outbye it may be expected that the air is clearer and less obstacles therefore increased distance to successive caches within the limits of the apparatus selected for use. Need to protect caches from vehicle damage and roof falls. Especially where chemical oxygen self rescuers are stored, if damaged and potassium superoxide (KO_2) exposed to water there is potential for a fire. Cache must be able to be located in poor visibility. Example in South Africa use siren & strobe system. Cached units should be a minimum of 10% more than the maximum number of people in the area who may need to access the cache. People need to be trained to take only one apparatus, additional control is provided by having long duration & therefore heavier units than those worn on the belt.
Medical Issues	The escape strategy needs to address those persons who may be injured or may be unable to wear a SCSR because of medical or fitness reasons.	The provision of refuge facilities for these persons needs to be considered The deployment in the mine of such afflicted persons needs to be considered.
Training	Competency required by the trainer Competency required by miner Competency of maintenance personnel	Mine trainer should be accredited by the Supplier as having a suitable level of knowledge and to cover such things as donning, doffing, expectation of heat and breathing resistance, anxiety, humidity, speed of travel, collapse of colleague. Miners able to demonstrate competency in the areas specified above. Be able to demonstrate an appropriate level of training and understanding of the technology and issues pertaining to the apparatus. Be able to demonstrate a knowledge of the management system.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
	Refresher training Change over in irrespirable atmosphere Communication between persons wearing self rescuers Collapse or injured colleague	South African example: • class room training of each person on return from annual leave • 3 monthly on the job challenge testing of randomly selected persons to test skill in donning a self rescuer apparatus and to test retained knowledge • 6 monthly thorough on the job SCSR training of entire 'underground' workforce • annual evacuation of mine Effective procedure needs to be devised and the procedure be included in the miner's training program Pre-planned protocol needs to be devised and included in the training program. Pre-planned protocol needs to be devised and included in the training program.
	Training aids	Policy determined in conjunction with the workforce and procedures be included in the training program. Sufficient number of training units - these should demonstrate breathing resistances. Decontamination of training units, hygiene of re-packing.. Supplier of the apparatus should have available various training aids in the form of demo units, videos, hand-outs, posters etc.
Transportation	Impact on the integrity of the apparatus by daily carrying - vibration minimisation.	Vibration can lead to powdering of the chemicals and/ or physical damage resulting in reduced service life.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
Management Control	Management to nominate a person to be responsible for the overall system including implementation Issue/Return Personal versus pool system Shared / double shift apparatus Inspection procedures	The system is to be documented & include auditing protocols to ensure that practice is aligned to the documentation. The system needs to be reviewed and up-dated in accordance with review outcomes and best practice. The documented system should specify the records to be kept and for what period. The system must identify roles and responsibilities for people at the mines and the supplier in maintaining the integrity of the self rescuer apparatus. Access procedures to apparatus and who has issue responsibility must be specified; Who is responsible for return of apparatus at end of shift; Best practice is for personal issue - tendency to restrict misuse and abuse Service life reduced as it is based on single shift use. Procedures for inspection of belt worn & cached units should be included in the system documentation.
	Minimise the apparatus being subjected to excessive vibration	Excessive vibration can lead to powdering of chemicals and reduced service life, eg if stored on vehicles.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
Maintenance	Frequency of inspection by mine personnel Rejection criteria	Integrity testing for belt worn & cached units. • All SCSR's in the face area to be checked to ensure integrity of seals, external damage and moisture indicator (where fitted) at least every working day. • belt worn units should be maintained in a clean condition- ingrained dirt may effect seals & disguise damage. • all apparatus should be subjected to inspection / testing as specified by the manufacturer • all apparatus should be identified for inclusion in a functional performance monitoring program based on the date of manufacture engraved onto the apparatus. • storage or cached units - weekly visual check • carried or belt worn apparatus subject to visual inspection daily Any apparatus which has visible external damage at the seal area or seal is not intact or has been tampered with, has dented case 12mm or deeper (including caps and sides of the apparatus) or as specified by the manufacturer, has a visible puncture in the case, or the indicator (where fitted) has changed colour MUST be removed from service immediately. In order for apparatus to be properly inspected it must be removed from any carrying pouch and any extraneous covers not being an integral part of the external case should be removed so as not to inhibit examination.

Self Rescuer Apparatus

Category	Issues to be considered	Notes
	Spare parts supply	Damaged units are to be refurbished only by the manufacturer or authorised agent. The manufacturer or authorised agent is to certify the integrity of any repaired apparatus.
On going Monitoring Program over service life	The apparatus being carried/cached will perform satisfactorily when required to be used.	• Apparatus should be inspected for structural durability. • Apparatus should be tested to ensure integrity of seals. There is a need to routinely test the integrity of the container seals for both filter type self rescuers and chemical oxygen apparatus at the mine site in a manner recommended by the manufacturer. • Chemical oxygen self rescuers may be subjected to a pressure test to ensure the integrity of the seals. It should be noted the KO_2 chemicals may be more sensitive to moisture than a moisture indicator if fitted. The indicator may revert close to its original colour regardless of KO_2 deterioration. On the other hand, a satisfactory pressure test of in-service units does not necessarily exclude the possibility that moist air has been sealed into the unit thereby causing KO_2 deterioration over time. Maintaining the integrity of the seal is vital to ensuring satisfactory performance. • Functional performance checks shall be conducted on a breathing simulator in accordance with the monitoring program (chemical oxygen self rescuers) flow chart, page 31of this guideline.
Records	Colliery to record service life, allocation & maintenance histories.	Consideration could be given to transponder cards fitted to self rescuers for automatically registering unit use and for updating mine record system.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: GUIDANCE SYSTEMS / LIFELINES

Following a fire or explosion sight may be severely restricted leaving the escaping mineworker to guide himself to safety by touch and hearing.
It is against this scenario that the adequacy of guidance systems should be judged.

Category	Issues to be considered	Notes
System types	Various guidance systems have been proposed to aid escape in low visibility following a fire or explosion.	Systems include combinations of: • lifelines fitted with directional cones, one way gates or reflective signs • conveyor structure / control cable • training cables • strobes and sirens • signs and arrows • short lengths of hose or strips of conveyor belt hung from roof • barriers to cordon off roadways/ cut-throughs • electronic sight and sound emitting devices Lifelines fitted with directional cones appear to have few shortcomings and are recommended as an element in any guidance system.
Survivability	Guidance systems need to be robust.	Passive systems such as lifelines should be of robust construction with high resistance to damage from fire and as far as reasonably practicable explosion. It is recognised that in an explosion there is a significant risk that such devices may be destroyed. While conveyor structure provides an escape path indicator it may also be destroyed in an explosion.

Guidance Systems / Lifelines

Category	Issues to be considered	Notes
		Active systems with battery powered backup are considered to be more likely to withstand the effects of an explosion. However further research and development may be required before acceptable active systems are available. An electronic sight and sound emitting unit developed in South Africa has yet to prove its reliability and effectiveness. The lights are of no use in zero visibility and the audible signals have been found to be confusing and disorienting.
Positioning	Lifelines need to be readily accessible.	A lifeline must be positioned so as to provide ready access and convenience for escapees and must be protected where liable to damage from everyday work activities. This may mean hanging higher across roadway intersections or hanging along the roof line in such a manner that the line is brought easily to a convenient height when needed. Lifelines should commence adjacent to working places with their most inbye point clearly marked. An alarm or strobe light, remotely activated, would assist the location of this point. Cables traced from mobile equipment such as shuttle cars and continuous miners may be used to provide guidance from the face area to a gate end box where a lifeline may commence. This system is not optimal however as trailing cables provide no indication of travel direction.

Guidance Systems / Lifelines

Category	Issues to be considered	Notes
Direction of Travel	In circumstances of limited or zero visibility the direction to safety may not always be apparent.	Cones securely attached to a lifeline appear to be a good physical indication of travel direction. Spacing of the cones on the lifeline should not exceed 20 metres. Systems utilising electronic sight and sound indication need to be proved in the underground environment. Indicators / alarms used to guide persons may be more effective if located at eye level. Special arrangements need to be considered for structures such as overcasts and belt overpasses to ensure lifeline is not lost and travel unduly impeded. When alternative travel ways are encountered in an escapeway, clear indication in the form of a physical barrier to entry, may be appropriate. Consideration shall be given to outbye workers who need to have clearly identifiable access points to Primary Escapeways.
	A guidance system is required along escapeway to identify cache / refuge chamber positions	See also elements: Change-Over Station & Refuge Chambers
Obstacles	Obstacles that impede passage will raise individual stress levels, increase effort & decrease rate of travel.	Clear walkways, clear of obstructions, should be established in escapeways adjacent to the lifeline. Walkways need not be full heading width but must be sufficient to allow unhindered passage. US Federal Regulation requires escapeways to be maintained to at least a height of 1.5m from mine floor to roof and not less than 1.8m wide except where specified and then not less than 1.2m wide.

Guidance Systems / Lifelines

Category	Issues to be considered	Notes
Continuity	A lifeline is only valuable & effective if it is continuous throughout its length.	Lifelines should be continuous to a place of safety. A schedule of regular inspections to physically prove continuity is advisable. Frequency of inspection is dictated by risk of damage. It may be possible to check continuity by electrical means if a conductor is embedded in the lifeline.
		At Middelbult Colliery S.A. the lifeline system runs from the face area to the nearest refuge bay. The lifeline is based on a single pair electric cable. The cable is powered and a light connected to its end acts as a constant indicator of continuity. The line is hung along the roof and is readily pulled down for use.
Monitoring of Travel	The location of individuals underground following an emergency event is an important aspect in management of an incident.	Systems are at an experimental stage where microswitches embedded in a line indicate remotely the number of individuals who have passed that point in the lifeline. Progress of this initiative should be monitored (CSIR Miningtek - South Africa).
Training	An escape system is only effective if all individuals are adequately trained.	Training in escape philosophy and procedures need to be thorough and regularly tested. (Note that they may vary from site to site). Individuals must be given the opportunity to routinely travel escapeways Limited visibility training sessions using blindfolds or sandblasted goggles is recommended to reinforce the importance of lifelines and as a conditioning process simulating the environment that may follow an explosion or fire underground.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: ESCAPEWAYS AND TRANSPORT AIDED ESCAPE

The ability of persons to escape from mines will be enhanced by the provision of designated escapeways which are developed, constructed and maintained in accordance with the following guidance notes.

Category	Issues to be considered	Notes
Primary Escapeway	The Primary Escapeway must be ventilated with intake air.	As vehicular travel will in most cases provide the best option for rapid escape the Primary Escapeway should where practicable be designed for vehicular escape. For existing mine workings, consideration should be given to upgrading travelling roadways to a standard in keeping with this document.
	A segregated intake roadway (not conveyor roadway) offers the best chance of maintaining an uncontaminated airway following a fire or explosion.	Survival prospects of persons escaping from a fire or explosion underground are enhanced by providing segregated intake-air escapeways to all parts of a mine. The Primary Escapeway to be separated from the conveyor roadway from the surface to and including the first cut-through outbye each loading point. Having the Primary Escapeway as a segregated escapeway is a requirement of U.S. legislation. Queensland coal mines will be required to have segregated intake escapeways in all new mines and new developments in existing mines.
Secondary Escapeway	An alternate or secondary escapeway should be designated for use where the primary escapeway may not be the most practicable route for escape	The secondary escapeway must be separate and distinct from the Primary Escapeway. It should be capable of being traversed on foot in reasonable walking conditions. Where the term 'second means of egress' is used training should make it clear that this is the designated secondary escapeway.

Escapeways and Transport Aided Escape

Category	Issues to be considered	Notes
Travelling conditions	The condition of an escapeway plays a major role in reducing escape times. Conditions which may slow down the speed of escape include: • Roadway height of less than about 1.8 metres • Roadways with numerous turns or misalignment, increasing disorientation • Narrow walkways or roadways with installed equipment • Water covered roadways, muddy floors, uneven floors and floors with loose coal and debris • Ladderways for access onto overcasts	Travel speeds increase with increasing seam height until a miner can walk fully upright at about 1.8m. U.S. legislation requires that escapeways be maintained to a height of at least 1.5m from mine floor to roof, excluding the thickness of any roof support. Tests in the U.S. indicate that wearing a respiratory device will decrease travel speed by approximately 15% in any seam height or condition of entry. Travel speeds along a longwall chock-line are roughly 50% of normal travel speeds for the same seam height. Width and alignment of escapeway should be such as to allow unrestricted travel. U.S. legislation requires the escape path to be not less than 1.8m wide except where restricted by supplemental roof support and then not less than 1.2m wide. Swillies where water can accumulate should be avoided, or where this is not feasible, provision should be made for automatic dewatering to reduce any restrictions to travel. Escapeways designed for vehicular travel should be maintained in good condition to allow fast transit. Roadway supports and fixed equipment including cables should be securely fastened to prevent dislodgement either by explosion forces or equipment interaction. Consideration should be given to providing stairway or ramp access to overcasts set on an angle of not more than 45 degrees from the horizontal. A sturdy handrail should be fitted, continuous up the stairways and across the overcast.

Escapeways and Transport Aided Escape

Category	Issues to be considered	Notes
Construction	Stoppings may fail in a fire or explosion	Escapeways should be segregated from other roadways by the construction of substantial (minimum strength equivalent to single brick stopping) fire resistant stoppings. Access doors should be self closing and latching and be of substantial construction.
Visibility in escapeways	In conditions of low visibility escaping persons have difficulty in determining the most appropriate escape path.	Systems should be installed to clearly indicate the correct travelling route whilst in the escapeway. See element: Guidance systems / Lifelines
Fire risk and control	Equipment used or installed in escapeways may become a fire source causing contamination of the intake escapeway air.	Installed fixed and mobile equipment in primary escapeways should either be fireproof, fire resistant or fitted with fire suppression systems. Where fixed electrical or diesel equipment is to be located in primary escapeways there should be a risk assessment where issues such as ventilation, monitoring, automatic protection and cut-off devices, fire suppression and early warning systems are considered and appropriate devices and systems installed.
	To reduce the risk of fire and suspension in air of matter following an explosion, as far as practicable all loose coal and coal dust should be cleaned up and removed.	High standards of stonedusting should be maintained in the primary escapeway to reduce the impact of an explosion or fire. It should be recognised that stonedust raised in an explosion contributes to reduced visibility.
Type of vehicle required to assist in escape	Diesel powered equipment may not be suitable post explosion or major fire due to the reduced oxygen content in the mine atmosphere.	Consideration should be given at mines with extensive underground workings to using battery powered equipment to provide vehicular escape. A fire suppression system capable of manual and automatic activation should be fitted on all battery vehicles.
Vehicle carrying capacity	Vehicles should be capable of carrying all persons located in a panel/ working area to safety.	

Escapeways and Transport Aided Escape

Category	Issues to be considered	Notes
Collision hazard	Where vehicles travel in reduced visibility there is a chance of collision with persons or other vehicles.	Consideration should be given to equipping vehicles with an effective signalling system for use in emergency low visibility situations.
Guidance systems for vehicles	In situations of low visibility travelling speeds may be reduced significantly.	Consideration should be given to providing vehicle guidance systems for use in low visibility conditions.
SCSR's	Consideration should be given to storing a number of SCSR's on personnel transporters.	Due to the effects of vibration on self rescuers that utilise chemicals for O_2 generation or CO_2 scrubbing these units may be unsuitable for caching in transporters. Any SCSR's stored in vehicles should be in addition to those determined necessary to be stored in caches.
Training in use of escapeways	In times of stress and poor visibility persons easily become disorientated.	Training systems should be established and sessions conducted on a regular basis to equip mineworkers with the ability to find their way from a variety of locations to the designated escapeways and then to a place of safety. Training should reproduce as realistically as possible the problems faced in locating escapeways under low visibility conditions. Where new hazards are introduced, such as the location of a compressor underground, the effect on current escape systems should be assessed and appropriate measures and training implemented.
	Escape from a panel may have several routes depending upon the site of a fire in relationship to the various air splits leading to the area at that time.	All routes need to be clearly distinguished and appropriately equipped and personnel must understand the strategy to choose the appropriate route.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: CHANGE-OVER STATION

The ability to escape is enhanced by changing over self rescuers in respirable air. This situation is facilitated by providing intake escapeways of suitable quality and integrity. Where escapeways are found lacking on risk assessment purpose built respirable air changeover stations may be required. As a respirable atmosphere cannot be guaranteed all training should assume an irrespirable atmosphere for self rescuer changeover.

Change-Over Station (COS)	A place designed for the safe storage of self rescuers and where efficient change over of self rescuers in mine atmosphere is facilitated.
Respirable Air Change-Over Station (RACOS)	A purpose built chamber designed for the safe storage of self rescuers and for providing and maintaining a safe atmosphere for self rescuer change-over.

Category	Issues to be considered	Notes
Escape philosophy	Whether COS's or RACOS's should be provided	Considerations in assessing need for a respirable air chamber may include: • RACOS are preferable. • Where the mine ventilation system provides a choice of segregated intake escapeways there may not be a need for RACOS's. • Where stoppings and seals on the intake side of the working place are of substantial nature there may not be a need for RACOS's • See element 'Refuge Chambers' esp. note on risk of personnel staying in RACOS's. • See element 'Escapeways and Transport Aided Escape';
	Advantages of respirable air changeover	• NIOSH have identified a 90% success rate for changeover where multiple donnings are required during an escape. Success on each donning is mutually independent. • Changeover in fresh air facilitates communication to the surface and also allows communication between escapees. • A respirable atmosphere changeover assists in reducing anxiety and panic.

Change-Over Stations

Category	Issues to be considered	Notes
	Overseas practice	United States: There are no MSHA rules or standards for cache construction. US Federal Regulations require that each miner be provided with a 1 hour-rated SCSR and MSHA works with mine management to develop a plan that delivers miners to a point of safety. Where SCSR's are stored these are generally in dust proof cabinets with change-over made in mine atmosphere. Reliance is placed on proper training and the integrity of mandatory segregated intake escapeway systems. South Africa: Miners are generally required to escape to a refuge chamber where they are to remain and await rescue. The refuge chambers are usually connected to the surface by a borehole for the supply of fresh air or in some cases are furnished with a chlorate candle for O_2 supply and a means of scrubbing CO_2. Refuge chambers normally are not cache points for SCSR's. 90 minute escape sets being transported in by rescue teams to effect escape. France: Small lightly fabricated container style respirable air change-over stations are provided near each working panel of HBL Group mines. While they would be uncomfortable for anything but a short stay they have proven to be adequate in terms of their escape strategy. They are provided with long duration SCSR's, telephone communications to surface control room and are maintained in a positive pressure state by connection to the mine compressed air-line system.
Air Supply to RACOS	A sufficient quantity of respirable air must be provided and maintained.	Alternative means of supplying breathable air, in general order of preference are: I. Direct borehole connection to the surface with attached fan II. Filtered compressed air III. Chlorate Candle IV. Compressed air or O_2 bottles

Change-Over Stations

Category	Issues to be considered	Notes
	A means of preventing ingress of toxic gases must be provided.	Suitable air flow rate and pressure. May need an antechamber/ airlock system.
	The air supply system may be damaged by fire/explosion.	Security of air supply is increased by using a back up source. Acceptable sources listed in order of preference [‘Rescue Shelter Analysis for Coal Mines’, MSHA (1973)], are: I. Borehole to surface with compressed air supply line; II. Two compressed air lines through the mine via different pathways; III. One compressed air line with back-up air purification and oxygen supply system.
Air Monitoring	Persons using a fresh air change over facility need to know the status of the atmosphere within and outside the shelter	Shelters should be supplied with means for measurement/ monitoring of O_2, CO and CO_2
Construction	RACOS may be damaged by fire/ explosion and may leak contaminated air.	RACOS may be required to resist the force of an explosion, the products of a fire/ explosion or both. Construction requirements will depend on the proposed use, potential hazards and level of risk for which the station is designed. A chamber’s ability to withstand an explosion is limited and it is almost impossible to construct doors that will not be damaged in an explosion.
	New developments	An alternative to near face RACOS is being developed by CSIR Miningtek, South Africa. Called a Mobile Air Rescue Station (MARS), the skid mounted unit carries compressed air cylinders and distributes air to open circuit smoke helmets facilitating communication. The efficacy of the unit has not been established.
	Protection from dust	Self Rescuers should be stored in dust proof cabinets

Change-Over Stations

Category	Issues to be considered	Notes
Access	The atmosphere inside a RACOS may become contaminated when persons enter and leave.	An air lock / antechamber may be used to maintain inside air quality. The antechamber should be large enough to allow safe access for men carrying a stretcher. RACOS in French mines generally do not have an antechamber.
Location	Duration of self rescuers	COS / RACOS should be located within the duration range for the self rescuers provided. Post explosion conditions, distance, walkway dimensions and conditions, guidance, visibility and physical fitness are all factors affecting time and ability to reach a safe place. See Element: Self Rescuer Apparatus
	Identification	COS / RACOS should be easily identifiable and must be able to be located in poor visibility. Appropriate guidance system/s should be provided to aid location.
	Inundation	COS / RACOS should be located to prevent inundation with water.
	Damage from explosion	The force of an explosion and any subsequent movement of equipment and material may damage and/ or prevent access. In locating RACOS consideration should be given to: • adequacy of roof and rib support • the location of equipment and structures that in an explosion may be moved to block the entrance to or egress from the station or damage the station. COS / RACOS should be located outbye the high risk face fire/ explosion area and away from the most probable direction of an explosion.

Change-Over Stations

Category	Issues to be considered	Notes
	Differential pressure leakage	RACOS located in cut-throughs should only be constructed between two intakes or two returns so as to prevent differential ventilation pressure from forcing mine air into the chamber.
Capacity	Chamber dimensions and air supply requirements	Need to cater for the maximum number of persons that may be in that area at any one time.
Communication	A system should be established for communication to the mine surface control room.	For communication systems see Element: Communication. Independent communication via a pre drilled borehole is the most secure.
	Alternative communication measures	Consideration should be given to the provision or development of basic communication signals/methods for use if breathable air is disrupted or not available in RACOS e.g. audible signals over phone.
Maintenance	Will the RACOS be fully functional when needed?	Inspections and maintenance should form part of the Emergency Escape system. There is a need to develop a check list for regular, perhaps weekly and quarterly audits.
Training	Will escapees be able to find the RACOS and ensure their safety while using it?	Regular practical training in finding and using change-over station facilities is essential. A training program should be developed by the mine operator, to be included in the main training plan for the mine.
	Training in SCSR change-over should assume an irrespirable atmosphere	As a respirable atmosphere cannot be guaranteed all training should assume an irrespirable atmosphere for self rescuer changeover.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: REFUGE CHAMBER

A Refuge Chamber (RC) is an underground shelter designed to protect miners from the bi-products of a mine fire or a 'limited' explosion until rescued. The design capacity and design duration of occupancy should be specified.

Category	Issues to be considered	Notes
Escape philosophy	Are refuge chambers necessary, desirable or undesirable?	Rescue chambers provide a secondary survival capability in the event that all other avenues of escape are blocked and a haven for persons who because of injury, medical or psychological reasons are unable to continue their escape. Refuge chambers may be desirable where in shaft access mines there is reliance upon mechanical means of escape and in physically isolated areas of a mine where access is restricted. In making a decision on the desirability of providing refuge chambers consideration should be given to the risk of seducing miners away from self escape and the ability to rescue men who choose this option. The mine emergency escape plan should include a strategy for rescuing men from the chamber; ref. TG4 Guideline for Aided Escape. Consideration should also be given to the risk of explosion and the demands to which the refuge construction may then be subject. The 'Emergency Preparedness and Mines Rescue Guidelines' of the Mines Rescue Board of NSW recommend against entry of mines rescue teams if the underground environment contains a flammable atmosphere and a known ignition source. Teams are also recommended against passing through or working in an atmosphere that is passing through or trending towards an explosive atmosphere.

Refuge Chambers

Category	Issues to be considered	Notes
	Will it be possible to rescue persons who take shelter in a refuge chamber?	Options for rescue of trapped or sheltering miners are limited. While refuge chambers are used extensively and successfully in South Africa to provide a safe place for men to await rescue this option is not consistent with the current thinking in Queensland or New South Wales; ref. ‘Emergency Preparedness and Mines Rescue Guidelines’, 1998 of Mines Rescue Board, NSW. It is therefore considered unlikely that rescue teams will be sent into a mine where concentrations of gas indicate there may be a chance of explosion or the mine atmosphere is highly toxic. A refuge chamber with escape borehole capability provides an alternative escape system where the risk of roadway escape is considered too high. The use of escape boreholes is covered as a separate escape element in these guidance notes.
	Overseas practice	United States: Refuge chambers are not mandatory in US coal mines. A paper written by the Pittsburgh Technical Support Centre entitled ‘Rescue Shelter Analysis for Coal Mines’, MSHA (1973) cautioned “when installed, a rescue shelter must be considered a primary survival tool. Thus great caution should be taken in specifying its construction, communication, life support, location, and associated training, and maintenance”. Draft design guidelines for (‘explosion proof’) refuge chambers were developed by the United States Bureau of Mines (Mining Research Contract Report, 1983) but were not adopted as official recommendations. The need for rescue chambers apparently seen only in cases where the integrity of the intake escapeway is destroyed or where there is only one escapeway available.

Refuge Chambers

Category	Issues to be considered	Notes
	Overseas practice cont.	South Africa: Refuge bays are mandatory and are a critical element in their escape strategy. They are to be provided "within easy reach of workmen and within the limits afforded by a self rescue device". They are not required to be explosion proof but are to be inaccessible to air containing noxious smoke, fumes and gases. Self rescuers are generally not stored in refuge chambers, miners being trained to await rescue. There are many documented examples of where sheltering mineworkers in both coal and gold mines have been led through smoke filled roadways to safety by rescue teams. 90 minute self-contained self rescuers generally being taken in for use in the rescue. The Ingwe Group of Collieries in SA have now introduced a total escape plan for all its collieries and 90 minute SCSR's are now installed in underground caches. France: Small lightly fabricated container style respirable air change-over stations are provided near each working panel of HBL Group mines. While they would be uncomfortable for anything but a short stay they have proven to be adequate in terms of their escape strategy. They are provided with telephone communications, long duration SCSR's and are maintained in a positive pressure state by connection to the mine compressed air line.
Air Supply	A sufficient quantity of respirable air must be provided.	Alternative means of supplying breathable air, in general order of preference are: I. Direct borehole connection to the surface II. Filtered compressed air III. Chemical O_2 generation (Chlorate Candle) IV. Compressed air or O_2 bottles The Mines Rescue Service of NSW advice for barricading includes a statement 'a person at rest requires 1 cubic metre of air per hour.

Refuge Chambers

Category	Issues to be considered	Notes
	A means of maintaining a respirable atmosphere and preventing ingress of toxic gases must be provided.	Where a borehole or compressed air line supplies fresh air to a chamber a suitable air flow rate needs to be maintained to provide sufficient oxygen and remove respired CO_2 and a suitable pressure maintained to protect from infiltration of hazardous gases. Where chemical oxygen generation systems are used to supply O_2, the sheltering persons may be required to wear a face-mask fitted with a soda-lime scrubber cartridge. Caution should be exercised in their use as there is no indication when they have expired. Alternatively a CO_2 scrubber may be incorporated with the chlorate candle system. Protection from infiltration of hazardous gases into the chamber should be addressed. When utilising compressed air cylinders protection for the cylinder banks is important. They also take up considerable room. For example, at a consumption rate of 20 lpm, 20 persons for 12 hours would require 288,000 litres of air. If BOC's 'K' size cylinders capable of delivering 11,300 litres each are utilised, 25 cylinders are required.
		As CO_2 builds up to dangerous levels in the chamber before O_2 falls to dangerous levels airflow estimates need to be based on the minimum airflow needed to hold down the CO_2 level to a tolerable concentration. The impact of metabolic heat build up in a refuge chamber should be understood.
	The air supply system may be damaged by fire/explosion.	Security of air supply is increased by using a back up source. Acceptable sources listed in order of preference ['Rescue Shelter Analysis for Coal Mines', MSHA (1973)], are: I. Borehole to surface with compressed air supply line; II. Two compressed air lines through the mine via different pathways; III. One compressed air line with back-up air purification and oxygen supply system.
Air Monitoring	Persons taking refuge need to know the status of the atmosphere within and outside the shelter	Shelters should be supplied with means for measurement/ monitoring concentration levels of O_2, CO and CO_2.

Refuge Chambers

Category	Issues to be considered	Notes
Construction	RC may be damaged by fire/ explosion and may leak contaminated air.	RC may be required to resist the force of an explosion, the products of a fire/ explosion or some combination. Construction requirements will depend on the proposed use, potential hazards and level of risk for which the station is designed. A refuge chamber's ability to withstand an explosion is limited and it is almost impossible to construct doors that will not be damaged in an explosion. An example of a South African type refuge chamber is a single entry cut into solid coal with an antechamber made from two 0.4 metre thick plastered and painted stoppings equipped with self closing steel man doors. The door frames are sealed with rubber lining and leakage controlled by maintaining a positive pressure via a surface connected borehole.
Access	The atmosphere inside a RC may become contaminated when persons enter and leave.	An air lock / antechamber may be used to assist maintenance of inside air quality. The antechamber should be large enough to allow safe access for persons carrying a stretcher.
Location	Duration of self rescuers	RC's should be located within the duration range of the self rescuers provided. Post explosion conditions, distance, walkway dimensions and conditions, guidance, visibility and physical fitness are all factors affecting time and ability to reach a safe place. See Element: Self Rescuer Apparatus

Refuge Chambers

Category	Issues to be considered	Notes
	Identification	RC's should be easily identifiable and must be able to be located in poor visibility. An appropriate guidance system should be provided to aid location. South African mines use integrated systems such as 'siren and strobe'. SA research has found that blue light is the most easily seen in dense smoke. Narrow strips of conveyor belt diagonally cut so as to indicate direction may be hung from the roof across escape travelling roads to indicate refuge chamber location. Chamber doors are provided clear and identical numbering both on inside and outside and on the surface structure of the chamber air supply borehole.
	Inundation	RC's should be located to prevent inundation with water. Above the level to which water may accumulate if dams and pipelines fail, and outside areas which can be expected to flood within a few weeks if pumping stops.
	Damage from explosion	The force of an explosion and any subsequent movement of equipment and material may damage and/ or prevent access. In locating RC's consideration should be given to: • roof and rib support in and around a site • the location of equipment and structures that in an explosion may be moved to block the entrance to or egress from the station or damage the station. RC's should be located outbye the high risk face fire/explosion area and away from the most probable direction of an explosion.
	Differential pressure leakage	Chambers located in cut-throughs should only be constructed between two intakes, between two returns or into a stub so as to prevent differential ventilation pressure from forcing mine air into the chamber.

Refuge Chambers

Category	Issues to be considered	Notes
Duration of Occupancy	Persons may need to remain in a RC for an extended period.	In the US the minimum duration for planning purposes is 14 days, given as 'a reasonable design time for rescuers to reach entrapped miners via drilling of an escape borehole' (Mining Research Contract Report, 1983.
Capacity	Refuge Chamber	Should be designed to accommodate the maximum number of persons who may have to use them. U.S. Civil Defence Agency have a minimum floor space requirement of 1.4 m^2/ person. Added to this is an area for storage of emergency supplies and equipment.
Provisions	Provisions sufficient to sustain the number of persons that may need to seek shelter should be stored in Refuge Chamber's.	RC provisions may include: stretcher and first aid equipment, food and water, tables/ seating, toilet facilities, lighting. Odour control should also be considered for RC's.
Communication	A system should be established for communication to the mine surface control room.	Independent communication via a pre drilled borehole is the most secure. For communication systems; see Element - Communications.
	Alternative communication measures	Consideration should be given to the provision or development of basic communication signals/methods for use if breathable air is disrupted or not available in RC e.g. chalk & blackboard, audible signals over phone.
Maintenance	Will the RC be fully functional when needed?	Inspections and maintenance should form part of the Emergency Escape system. There is a need to develop a check list for regular, perhaps weekly and quarterly audits.
Training	Will escapees be able to find the RC and ensure their safety while using it?	Regular practical training exercises in finding and using a refuge chamber should be conducted. A training program should be developed by the mine operator and included in the main training plan for the mine.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: BOREHOLES FOR PERSON ESCAPE

Where borehole escape is a significant element of an emergency escape system all necessary drilling and escape equipment should be provided on standby or the borehole should be pre-drilled.

Category	Issues to be considered	Notes
Positioning	Surface site features	The site should have all weather access, be level, clear of vegetation, services and any other obstacle to drilling. Sufficient area must be available for planned drilling and associated operations. The ground under and around where drilling rig is to be erected must be consolidated and capable of supporting the rig. It should be free draining and above flood level. Hole location/s should be surveyed and marked.
	Strata details / drillability	A geological section showing strata types and thicknesses from surface to underground should be prepared. Also advice as to whether the hole is likely to contain an aquifer or gas and on drillability and strata stability. Estimate of drill time to reach target should be provided. Underground roof conditions should be described, bed separation above workings should be established and documented.
	Target site	Drilling a borehole to intercept a refuge chamber may introduce roof control and leakage problems. In consolidated strata spalling may be a minimum but in loose rock the debris may present a hazard to sheltering miners. Unless positive air is supplied to the chamber the opening caused by the drill may permit leakage of toxic gases.

Boreholes for Person Escape

Category	Issues to be considered	Notes
	Target site cont.	In South African (S.A.) coal mines the prime strategy is to drill an escape hole to intersect the workings just outside a refuge chamber where men have taken shelter. In the U.S. consideration would be given to drilling into a refuge chamber from the surface. Where miners are not sheltering in a refuge chamber the strategy is to locate them (if necessary) using the Seismic Location System maintained by MSHA, drill a small probe-hole to establish communications and to sustain lives, then drill a rescue hole nearby.
Rig availability	Overseas experience	South Africa - On the recommendation of Ingersol Rand (US) the S.A. Chamber of Mines in 1977 purchased a DHD -124 downhole drill on a T-5 Drillmaster mounting for use in drilling escape holes into coal mines. The main power pack is a Spiro-Flo DXL -5000S mobile compressor capable of delivering 2.4m^3/sec of air at 850 kPa. This unit together with trailers loaded with drill rods and casing, rescue and workshop equipment and plant and a mobile crane, are garaged and maintained on standby at the Witbank Training College S.A. United States - Between 1971 and 1986 the USBM / MSHA, contracted with the Rowan Drilling Company of Texas the maintenance and operation of rescue drilling equipment. This contract was terminated in 1986 and no drilling unit is currently maintained on standby for mine rescue. Recent advice from the U.S. is that if the need arose there would be sufficient rigs available in U.S. industry for immediate deployment. Australia - No unit is currently maintained on standby for mine rescue. A contractor would have to provide a suitable rig on call. Rigs that with capacity to handle the downhole equipment as used in S.A. are scarce and available rigs most likely require modification. Specialist ancillary equipment would have to be purchased and maintained.

Boreholes for Person Escape

Category	Issues to be considered	Notes
	Mobilisation costs	The very high capital and maintenance costs incurred in having a drilling system on permanent standby for S.A. coal mines is being paid for by means of a levy on all underground coal mines. The working depths and surface terrain of many NSW mines make the drilling of borehole escapeways often impractical and the NSW and Qld coal industries are unlikely to support the establishment of an industry owned and maintained unit.
	Planning	Any mine manager who may need to drill an emergency borehole suitable for person escape, should plan ahead to: • locate and contract a drilling company with suitable hole making capabilities; • establish inventory needs for all escape equipment and contractor consumables; • locate all necessary escape equipment; • select potential drill sites and document geological details; • survey sites; and prepare an emergency response management plan
Hole specification	Diameter	South Africa - Minimum diameter hole drilled for escape is 560mm. They plan for a 635mm hole to be routinely drilled. If for some reason the hole has to be cased, this can be achieved and still allow for continuation of the hole at 560mm. Adequate tolerance is required to avoid locking of the rescue capsule. In S.A. a 430mm outside diameter rescue capsule is used to raise trapped men. United States - The largest of the 2 rigs maintained by Rowan Drilling Company was capable of drilling a 720mm diameter hole to a depth of 760 meters.
	Depth limitation	The maximum depth of hole will be limited by the power of the rig to handle and lift the drill rods and down hole equipment. Ability to flush cuttings from the hole may also be a limiting factor. South Africa - With the rig / drill string / Down Hole Drill (DHD) Hammer set-up as described in this document for S.A., this is about 270m.

Boreholes for Person Escape

Category	Issues to be considered	Notes
Drilling operations	Drilling options	• blind boring with DHD hammer; • blind boring with conventional rotary rig drilling full diameter; • blind boring with conventional drilling with core recovery; • conventional drilling of a pilot hole then milling / reaming. One pass drilling is normally quicker.
Drilling Operations cont.	Penetration rates	Air powered DHD Hammer has the fastest penetration rate and is the preferred method and the method adopted in S.A. A conventional rotary rig using mud as the drilling fluid is estimated to take 4-5 times as long to drill the same diameter hole as a DHD Hammer. South Africa - The T-5 Drillmaster / DHD-124 unit. is capable of drilling 9-10m/hr in coal measures (UCS 48 - 100 MPa) and 3-4m/hr in Dolerite (UCS 250 - 390 MPa). Set-up time on arrival at a pre-prepared site for this rig is about 1.5 - 2.5 hours. United States - A demonstration of the large rescue rig in 1971 at Munson mine West Virginia involved drilling to workings located at a depth of 240m. It took 8 days from the time the rig moved on site.
	Clearing cuttings	With blind boring, cuttings are removed to the surface principally by air, foam or mud. Up hole velocity is a critical factor in removing the cuttings. Where air flushing is used large diameter drill rods serve to reduce the annulus area to achieve the required air velocity. These are heavy and require a suitably modified drill rig with high lifting power to accommodate them. 508mm diameter drill rods are used in SA.

Boreholes for Person Escape

Category	Issues to be considered	Notes
	Clearing cuttings cont.	One NSW drilling contractor suggests that sufficient air can be supplied by three compressors operating in tandem, providing a total of 1.275 m3/sec (2,700 cfm) at 2.45 MPa (350 psi), to lift cuttings up the hole annulus when using 220 mm (8 5/8 inch) drill rods. Alternatively cuttings can be removed by flushing down a pre-sunk pilot hole. The potential for the cuttings to cause problems either in blockage or in the underground workings would have to be assessed.
Drilling Operations cont.	Hole stability	Suitable diameter casing needs to be available for installation in unstable ground at surface section of the hole. Where hole stability problems may be encountered at depth, intermediate casing may be required. Rapid setting cements may have to be employed to stabilise intermediate casing. The roof control system at underground target sites should be appropriate for safe penetration of drill bit.
	Danger of introducing explosive gas or holing into explosive gas.	Consideration should be given to the potential for ignition on holing the workings. Flammable gas may be intersected in the borehole strata and flushed into the workings on holing or an explosive atmosphere may have built up in the workings prior to holing. Preventative measures should be adopted to avoid an explosion.
	Danger from lightning strikes	Sth African's caution against casing boreholes with steel from surface to coal seam - potential to transmit an ignition source in an electric storm.
	Surveillance probe	Maintenance of a post surveillance probe fitted with video camera and audio communication system and capable of being lowered down a 150mm diameter borehole, should be considered for reconnaissance purposes.

ELEMENTS OF AN EMERGENCY ESCAPE SYSTEM

Element: COMPETENCY

Training and competence assessment is an integral part of the emergency escape system. The Mine Manager is required to have in place a system to ensure that all persons going underground and all personnel with duties under the emergency escape system are competent in their roles. As appropriate comments have been made in individual element tables, this element now considers issues in regard to training on the escape system as a whole. This element does not cover the training of rescue brigades under the NSW Mines Rescue Act.

Category	Issues to be considered	Notes
Training program	Aim	The training program should aim to: • achieve an effective response from personnel in the event of an emergency, • instil confidence in the equipment supplied and procedures laid down, and in the mineworker's own abilities to react to emergency situations effectively, and • ensure maintenance of effective levels of skill and knowledge.
Underground personnel	Testing of alert communication system and personnel response. Familiarity with what conditions require emergency escape response. Knowledge of possible environmental conditions in an emergency.	The Moura Task Group #2 recommendation of an annual requirement for all underground crews to undertake a practical exercise which tests the alert communication system and emergency evacuation plan has been implemented in Queensland. An additional requirement is for each crew to undertake an exercise annually, or when their workplace changes significantly, which tests employee evacuation, accounting for all persons, search and rescue and response to a medical emergency (this exercise may be practical or desk-top). The general South African strategy is to escape to a refuge bay and await rescue. Emergency exercises at Kriel Colliery are held quarterly where a simulated emergency is initiated and personnel retreat to the refuge. Some workers wear training SCSR units. Sometimes, reduced visibility is simulated through airborne stonedust. This exercise is also done where a crew moves to a new work area.

Competency

Category	Issues to be considered	Notes
Underground personnel cont.	Familiarity with escapeways and cache location. Competence in use of escape apparatus. Competence in refuge procedures where applicable. Competence in specific response procedures under the mine's emergency management system.	The Reumaux mine (HBL), in France, holds training sessions on SCSR's and the escape strategy every time a new longwall face commences. The Cumberland Mine in Waynesburg Pennsylvania USA, miners receive training in escape every 6 weeks.
Supervisor leadership	Need for additional training of front line supervisory level to strengthen leadership abilities under emergency conditions.	Many critiques of mine emergencies have stated that a crew's ability to effectively escape is greatly enhanced where there is a leader who: • is familiar with escape route options • has understanding of rescue techniques • has high level man management skills under stressful conditions.
Persons with responsibilities to maintain equipment under the emergency escape system	Clear definition of those responsible for the maintenance of equipment Training and competency assessment in roles	An assessment must be made of the need for "alternates" to persons with responsibilities under the emergency escape system to cover planned and unplanned instances were the nominated person is uncontactable. Allowance must be made for training and assessment of such alternates.

Competency

Category	Issues to be considered	Notes
Mine emergency management team	Defined roles and responsibilities Test of call-out system Test of response to emergency scenarios	The emergency system should define an emergency management team with clear role definition so that practical and/or desk top exercises can be carried out with the team to assess performance and areas for improvement.
External (to mine) emergency services	Identification of services required Agreed contact and response protocol Testing of call-out Relevant involvement in minesite training exercises	Training should include outside agencies where they are involved in specific emergency response activities. The Queensland Chief Inspector of Coal Mines has incorporated the Moura Task Group #2 recommendation of an annual requirement for a mine to select a minesite exercise where they would include contact with all external emergency services and ask "ARE YOU IN A POSITION TO RESPOND". Actual attendance is not required.
Visitors and contractors	Coverage of visitors and contractors in emergency escape training systems.	

Competency

Category	Issues to be considered	Notes
Types of exercises	'Self Reliant' versus 'Assisted' 'Practical' versus 'Desk top'	The effectiveness of the training provided and its retention by trainees should be validated by conducting emergency exercises. The work done by the Queensland Moura Task Group #2 defines emergency procedure exercises (and indeed real emergencies) into two types: 1. "Self reliant" is where the exercise tests services, personnel and infrastructure available at the minesite, and 2. "Assisted" which is a response to an emergency where the site accesses external aid. Such exercises may be of a practical nature or "desk top" which is an exercise that is designed to test system preparedness without requiring an actual response but is a paper, communication and acknowledgement exercise. The training plan behind the emergency management system would ideally contain an appropriate mix of such exercises. The exercises may also serve to indicate the adequacy of the other elements of the emergency escape system. Feedback from such exercises should assist in identifying improvement opportunities in strategies, procedures and equipment.
Competence of trainers	Vendor training Minesite trainers	The quality of the training program, and consequent retention of knowledge and skills by underground personnel, is heavily dependent upon the quality of the trainers. Where possible trainers, assessors and the training programs should be accredited.
Element specific training	'Issues to be considered' and 'Notes'	Reference should be made to the "Training" category included as guidance material for each specific element of the emergency escape system.

4.0

CLASSIFICATION OF SELF RESCUER APPARATUS