Guidance and Information on the role and design of safe havens in arrangements for escape from mines

This guidance represents good practice as considered by the Mining Industry Committee, representative of all sides of the underground mining industry. It was prepared, in consultation with the Health and Safety Executive (HSE), by its Escape and Rescue Operations in Mines Working Group.

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Introduction

Who should read this guidance?

1 This document is aimed primarily at mine managers and mine owners with a statutory responsibility for effective emergency planning. Others in the mine management structure, safety representatives and members of mines rescue service may also find this information useful.

2 It gives guidance on the role and design of safe havens and facilities for the exchange and recharge of self-rescuers. For the purpose of this guidance, the latter are referred to as semi-sealed safe havens. The guidance also covers location and use.

Legal provisions

3 The Escape and Rescue from Mines Regulations 1995 (ERM 1995) place duties on the mine manager to prepare, revise and give effect to the emergency plan. Where necessary, safe havens or facilities for the exchange and recharge of self-rescuers must be provided. The relevant regulations and associated Approved Code of Practice material is included in **Appendix 1**.

What is a safe haven?

4 A safe haven is a place with facilities including an independent air supply to maintain an atmosphere at positive pressure (eg greater than the surrounding atmosphere), so people can wait in safety until rescue arrives. There are two types of safe haven:

- a totally sealed installation, with airlocks and suitable environmental monitoring etc. where people can wait without wearing self-rescuers; or
- a semi-sealed installation where people can change self-rescuers or wait while wearing self-rescuers.

5 Safe havens need to have a telephone or tannoy so that people inside can communicate their presence and messages can be sent from the surface. Any equipment kept in the safe haven should be maintained and regularly tested in accordance with the manager's scheme for the mine.

Arrangements for escape

6 It is essential to have effective arrangements in place for the safe and prompt evacuation of people from mines, as well as taking measures to control the risk from fires and explosions.

7 Arrangements for evacuation usually require provision of self-rescuers for all people going below ground in mines. Managers planning escape strategies should not rely solely on self-rescuer manufacturers' nominal duration information for calculating the distance people can safely travel. Physiological and tolerability issues also need to be considered.

8 Effects of heat and humidity, as well as reduced visibility following an underground fire or explosion will limit the evacuation distance miners can attempt, before being under significant physical and mental stress. Properly designed safe havens at strategic locations will enhance the likelihood of survival.

9 Wearing a self-rescuer makes verbal communication and rehydration impossible. Self-rescuers can dehydrate the wearer's mouth and render them speechless due to the use of 'gag' type mouthpieces and nose-clips (as oppose to facemasks). In addition to self-rescuer duration, when assessing whether safe havens or facilities for the exchange and recharge of self-rescuers should be provided, it is important to think about:

- likely composition of the inhaled air (particularly for filter self rescuers);
- maximum distance to travel to reach a place of safety;
- travelling conditions and visibility;
- physical and mental effort required to escape; and
- temperature and humidity (the key findings of recent research are detailed in **Appendix 2**).

When should a safe haven be provided?

10 Where the risk assessment indicates escape to a place of safety is not likely to be reached by use of self-rescuers alone, after taking account of the above.

Role of a safe haven

11 Safe havens that are close to the workplace will provide escaping workers a **muster-station** to aim for, so it is important to have an informed mines rescue strategy. It may be possible to continue towards the surface and fresh air - this should always be the first priority.

12 However, it may be safer to remain in the safe haven and wait for assistance while rescue teams tackle the source of the fire or other problem. Commitment of mines rescue teams in hot and humid roadways or complicated mine layouts searching for unknown numbers of escaping miners is fraught with risk. International experience suggests that where mineworkers survive, using safe havens following an emergency, it can take up to 36 hours for rescue teams to secure their recovery.

Design criteria of a safe haven
13 Mine managers considering the provision of safe havens as part of a strategic emergency plan need to take into account a number of factors depending on the type of safe haven deployed:

Totally Sealed Installation (ACOP 52 – Type (a) ERM 1999)

Occupancy levels

14 Identifying the number of people likely to access the safe haven and estimating the duration of use is essential. Looking at shift patterns and distribution of workforce throughout the mine should help, bearing in mind shift changeover patterns. Duration of use is more difficult to estimate but as a guide, safe havens should extend the period of protection beyond the life of self-rescuers, keeping people safe until mines rescue teams can reach them.

15 The outer limit response time for rescue teams arriving at a coalmine surface should not exceed 60 minutes (ACOP 81 ERM 1995). While not bound by the same statutory provision, to be effective, miscellaneous mines rescue response times should be broadly similar. However, it will take longer for rescue teams to travel underground, especially if transport within the mine is no longer available. Additionally, a staged re-entry is often required to ensure the safety of mines rescue workers.

Air supply

16 Safe havens work by separating the people inside from the toxic atmosphere outside. Examples include:

- A sealed portable enclosure providing a storage battery back-up air-conditioned life-support mechanism with bottled O_2 supply and CO_2 scrubbers. These are suitable for large mines where transportation is reasonably convenient.
- A compressed air fed cement-block enclosure, shipping container or prefabricated structure. These tend to be more static arrangements.
- A borehole supplying fresh air via a compressor direct from the surface. This arrangement is particularly suited to relatively shallow mines.
- A large 'residual air' sealed void (typically 15m x 45m) with emergency bottled O_2 supply for 36 hrs. Such arrangements are found in salt mines with potential for large, stable, void areas.

17 An air/oxygen supply must achieve two prime functions:

- maintain a respirable environment; and
- maintain tolerable conditions in terms of heat and humidity.

Breathable compressed air supply

18 To determine the minimum safe haven compressed air supply, breathable air is defined as constituting a minimum O_2 content of 19% and CO_2 content not exceeding 0.5% (5000ppm).

19 During entrapment, it is assessed that individual O_2 consumption will be 0.5 l/min with a breathing rate of 12.5 l/min of fresh air. To maintain CO2 levels below 0.5%, an airflow no less than **85 l/min per occupant** is required (Brake & Bates, 1999).

20 During research for this guidance, nominal compressed air supply rates of 1000 cubic feet/min (0.5m^3/s) were quoted as typical for a large coalmine equating to **30,000 l/min**. Therefore, sufficient air would be readily available to maintain the safe haven at positive pressure and maintain a 'breathable' atmosphere for large numbers of people. However, studies confirm that the airflow rate necessary to maintain a tolerable thermal environment is significantly greater that that required for respiration alone.

Safe haven thermal environment

21 The challenge facing safe haven designers, in addition to providing adequate means of respiration, is maintaining thermal tolerability. To establish the criteria for maintaining a tolerable thermal environment within a safe haven, assumptions must be made for the physiological heat exchange mechanism:

- metabolic heat production of 120 W per person;
- target maximum core body temperature of 38ºC;
- people inside safe haven will strip down to minimum clothing;
- assume sufficient water to restore hydration; and
- assume occupants sit down and maintain 'low-level' activity.

22 Taking these assumptions into account, numerous other variables remain including, compressed air inlet temperature and humidity, virgin rock temperature, geothermal gradient, mine air temperature, dehydration levels induced by the use of self-rescuers, and numbers and rates of people entering the safe haven.

23 Based on compressed air input conditions of 26.5ºC @ 64% relative humidity, the minimum airflow estimated to maintain 'comfortable' conditions is 8.5 cubic feet per minute or **255 l/min per occupant** (eg three times that required to maintain a 'breathable' atmosphere).

Table 1 Analysis of safe haven air supply cooling potential

(Target air condition of air delivered to safe haven 26.5 C @ 64% RH)

	'Comfort' case 28ºC, 100% RH	**'Survival' case** 35ºC, 100% RH
Heat absorption by air, J / m^3	1,663	9,425
Heat absorption, evaporation, J / m^3	28,228	60,978
Total heat absorption, J / m^3	29,891	70,403
Minimum airflow per occupant, litres / min	250	100

24 Using the given compressed air example (**0.5m^3/s @ 26.5ºC @ 64% RH**), a safe haven of sufficient physical dimension could accommodate approximately **100 people**. Where ambient rock and air temperatures are high, or the compressed air is supplied with higher relative humidity, the occupant level and duration will be reduced unless additional measures are taken.

25 Additional cooling will extend the capacity and tolerability for safe haven occupants and could be achieved by a combination of:

- battery supplied air conditioning units in miscellaneous mines and non-flammable gas situations in coalmines (non reg.19 zones – Electricity at Work Regulations 1989);
- multiple compressed air inlet jets aimed at occupants;
- internal air movers (compressed air venturi or blade type); or
- restricted safe haven ceiling heights (maximise velocity).

26 To simplify matters, basic safe haven design prerequisites were established: maintain the lowest practical level of humidity in the compressed air supply entering the safe haven;

- safe haven wet bulb temperature should not exceed 28ºC ('comfortable') with an upper limit of 35ºC (probable limit for 'survival'); and
- maintain airflow velocity over the skin surface not less than 0.5m/s. (As a rule, below 38ºC, the higher the airspeed, the greater the cooling effect).

Standby breathable air arrangements

27 In addition to compressed air, mine owners and managers should consider what would happen if the compressed air supply became contaminated or interrupted and how this condition may be detected. Providing a secondary means of breathable air can extend survival chances. However, without compressed air or cooling, the thermal environment inside the safe haven could become intolerable. Once secondary breathing masks or hoods are on, the safe haven doors may need to be opened to reduce humidity. People wearing fresh self-rescuers should consider getting out of the safe haven entirely and into the main air current where it may be cooler (but contaminated). Examples of standby air-delivery arrangements can include:

- banks of large compressed air cylinders fitted with facemasks, hoods, or outlet nozzles; and
- spare sets of long duration self-contained self rescuers.

28 If the compressed air supply fails and people are committed to wearing airline hoods or masks, these facilities should be close to means of communication inside the safe haven.

29 Chlorate candles (oxygen producing canisters) were considered but due to their high thermal output, were discounted as a way to provide a standby oxygen supply inside a safe haven.

Location

30 Factors affecting escape and rescue measures should determine the location of a safe haven, for example:

- availability or otherwise of dual intake roadways;
- travel distances to fresh air from place of work;
- heat and humidity;
- escape route gradients; and
- distances of workings inbye from pit bottom etc.

Way-finding

31 Access to safe havens should be clear and free from obstructions. They should be easy to locate and special 'sensory' measures taken to identify them when visibility is limited. As an example, fluorescent way-finding roadway markers,

directional life-lines and continuously ringing the telephone in the safe haven could help the first group to find it. Once located, klaxon horns could be sounded from within the safe haven to assist others. External telephone bells could assist as a location finder.

32 Steel plates on the floor adjacent to crosscuts that vibrate under foot could also help people to find it.

33 Landmarks should be used to inform workers of the safe haven location and the remaining distance to the safe haven or other pre-determined landmark. Landmarks should be visible, audible or tactile (or preferably a combination) placed at a height and position that enhances the possibility of them being found in limited visibility. A constant approach to 'way-finding' should be adopted throughout the mine and the development of a workers 'mental map' will be enhanced through regular training.

Communication

34 It is essential to have effective means of communication in a safe haven. Where reasonably practicable, redundancy should be built in to the system with at least two means of communication provided. Ideally, separate routes would be chosen to run communication cables, which should be protected from physical damage. The positioning of the telephone/tannoy systems within the safe haven should be beside a map reading table and placed as far away as possible from sources of noise (eg compressed air inlet).

Food and drink

35 A supply of drinking water should be available. People entering a safe haven after wearing self-rescuers are likely to be dehydrated. Water can be supplied in sealed and sterilized containers (to prevent bacteria growth) or by application of the reverse osmosis technique (currently being evaluated). To maintain an individual's ability to thermoregulate, they need to drink at least one litre per hour. Nutritional emergency ration packs can be provided to replenish lost energy in order, where possible, to continue a staged escape or cooperate with rescue teams during a planned evacuation from the safe haven.

Environmental monitoring

36 Internal and external environmental monitoring will confirm the atmosphere inside the haven is safe without wearing self-rescuers and provide information on environmental conditions surrounding the safe haven. A multi-gas instrument is desirable, monitoring not only carbon monoxide (CO), but oxygen levels (O_2) and if possible carbon dioxide (CO_2). Note that O_2 reduction alone is not a reliable measure of CO_2 levels since there is a 5:1 displacement ratio. i.e. O_2 only makes up 1/5 of breathable air. The other 4/5 is nitrogen. Therefore, with only 1% reduction in O_2 levels, if displaced by CO_2, this could have a marked effect on breathing difficulty. Monitoring the wet and dry bulb temperatures inside the safe haven will assist in regulating the adequacy of the compressed air supply.

First aid equipment

37 First aid equipment should be provided with an emphasis on a supply of eyewash since people arriving are likely to suffer smoke exposure to their eyes (most self-rescuers have no goggles).

Toilet

38 People may need to stay in the safe haven for several hours. Sealed portable chemical toilets with modesty screens should be provided. Basic urinals with 'U' tube outlets could be fabricated into the safe haven wall.

Lighting

39 Once inside the safe haven, people should use their personal cap lamps sparingly to enhance their capability when resuming evacuation from the mine. Consideration should be given to the provision of chemical 'glow sticks' which provide emergency lighting.

Windows

40 Human factor studies suggest that providing a window in the safe haven so that people can see what is happening outside will reduce feelings of entrapment and lower the temptation to leave the safe haven until it is safe to do so.

Mine plans and writing

41 An up to date mine layout/ventilation/rescue plan should be visible in the safe haven next to the means of communication. A suitable writing surface with spare pens/pencils will aid escape planning.

Training

42 Advertising the safe havens policy and making sure workers are familiar with the safe haven location in the mine, will allow workers to develop confidence in the safe haven principle and its ability to protect them in an emergency situation. Regular safety briefings and use of safe havens during mock emergency drills are recommended.

Maintenance

43 Safe havens, communication devices and emergency equipment should be maintained under the manager's planned maintenance scheme.

Other

44 To reduce physical stress, backrests could be provided in addition to benches. Means of distraction, eg playing cards, dominoes etc. could be provided. This not only provides light relief but has also been shown to reduce stress levels and therefore minimise individual oxygen demand and physical heat output.

Semi-sealed Installations (ACOP 52 - Type (b) ERM 1999)

Changeover facilities

45 Guidance on the provision of this type of emergency equipment was developed by the Deep Mines Coal Industry Advisory Body in 2001 and is published in the HSC document *Guidance and information on escape from mines* ISBN 0-7176-2006-9.

Design

46 These semi-sealed safe havens can be pressurised canopies, compressed air/auxiliary ventilation outlets, or flexible enclosures maintained at positive pressure. They should be robust and compact and sited in gate roadways or development

headings as close as possible to the workplace and at appropriately spaced intervals throughout the escape route. Their position along the escape route should be prominently marked to assist in limited visibility.

Purpose

47 Intended primarily as a rendezvous for people escaping they should also facilitate the exchange of self-rescuers and rehydration as people carry out a staged escape from the inbye mine workings to a place of safety, eg unpolluted intake airway, type (a) safe haven or the mine surface.

Air supply

48 The independent air supply should be capable of maintaining the atmosphere inside a changeover facility below the Control of Substances Hazardous to Health Regulations (COSHH) 15 minute Workplace Exposure Limit (WEL) for carbon monoxide (CO). This will allow people to change their self-rescuers safely or extend the effective life of a filter self-rescuer for those choosing to remain at the changeover facility until rescued. Provision of changeover facilities will also give people the opportunity to rest for a few minutes and in certain cases, where the design incorporates a 'cool-haven' structure, provide some relief in hot and humid conditions before proceeding outbye.

Communication

49 Changeover facilities should be located close to a means of communication. If a telephone or tannoy cannot be fitted permanently inside the changeover enclosure, it should be practicable to fit a tannoy on a flexible cable which can be moved inside the 'clean air' environment to facilitate communication.

Replacement self-rescuers

50 One of the primary functions of a 'type b' safe haven is to facilitate the safe exchange of self-rescuers. In carrying out the risk assessment required by regulation 4 ERM 1995, the manager of every mine should consider what arrangements are suitable in terms of the provision of self-rescuers and where necessary, replacement self-rescuers. Where people depend on self-contained self-rescuers (SCSR) in long development headings and production district gate roadways, changeover will be almost inevitable and should be done safely. In many cases, change from a relatively short life SCSR to a long duration device will be appropriate.

Other equipment

51 As with the larger 'type a' safe havens, the chance of escaping in an emergency situation will be improved when careful consideration has been given to the equipment provided. To help people to survive while awaiting rescue or to escape, the following items would assist:

- environmental monitoring equipment to test the air outside the changeover station;
- drinking water;
- plans showing escape routes to fresh air or to other safe havens; and
- basic first aid equipment.

Safe haven performance evaluation

52 Because of the large numbers of variables in any design or location, it is only by thorough evaluation and review that the individual performance of a safe haven can be determined and the design refined accordingly. The safe haven design should be verified by appropriate testing and measurement to confirm that air delivery and other cardinal specifications are fit-for-purpose.

53 If part of the emergency plan, safe havens should be regularly used during mines rescue practices and annual mock evacuation drills, which are both statutory requirements.

Conclusion

54 Most underground workers in UK mines will go through their working life without experiencing a major emergency situation. However, statutory requirements place duties on employers and managers to ensure that in the event of an underground emergency, suitable contingency arrangements are in place. The extensive layout of modern mines combined with long gate roads and hot and humid conditions will limit rescue potential when breathing apparatus is required. Where this occurs, enhanced escape arrangements should be in place. Only by carrying out assessments that adequately address all foreseeable risks will 'effective arrangements' be maintained and statutory obligations satisfied.

Appendix 1 What laws apply?

Specific legislation dealing with escape and rescue from mines is contained within the Escape and Rescue from Mines Regulations 1995 (ERM 1995).

Regulation 3 of the Management of Health and Safety at Work Regulations 1999 (MHSWR 1999) requires that employers shall make a suitable and sufficient assessment of the risks to health and safety of their employees to which they are exposed whilst at work.

To develop an effective emergency plan (reg.4 ERM 1995), the manager shall have regard to any relevant risk assessment carried out under regulation 3. MHSWR 1999. The manager must also make a thorough review of his emergency plan:

- whenever there is reason to suspect that the current emergency plan is no longer appropriate;
- if there has been a significant change in the matters to which the plan relates;
- if the ownership of the mine has changed;
- if the risk assessment (reg. 3 MHSWR1999) has been reviewed;
- if the emergency plan has been put into action; and
- at least every 12 months.

Regulations place statutory duties on the manager for preparing, revising and giving effect to the emergency plan. The owner has statutory responsibility in accordance with regulation 6, the Management of Safety and Health at Mines Regulations 1993 (MASHAM) for making financial and other provision to secure the mine is managed and worked in accordance with the relevant statutory provisions.

Under Approved Code of Practice (ACOP) 14, ERM 1995, particular account will need to be taken of the conclusions of a risk assessment in relation to fire and explosion.

ACOP 14(c) ERM 1995 deals with the specific risks to people and their ability to escape to fresh (eg respirable) air assuming unfavourable circumstances, **which might reasonably be foreseen**, and the locations where people might be trapped. The ACOP specifies that issues to be considered include:

- the layout of the mine and numbers of people likely to be present in different parts, especially blind ends;

- the rate at which products of combustion might spread through the mine and the capacity of the ventilation system to dilute them;
- the walking time from the working area to fresh air, taking into account gradients; and
- the availability, if any, of transport that could be safely used.

Regulation 10 ERM 1995 requires that the owner of every mine shall provide where necessary, suitable self-rescuers and safe havens or facilities for the exchange and recharge of self-rescuers.

ACOP 51, ERM 1995 states where the time necessary to escape to a place of safety would exceed the life of a self-rescuer in use at the mine, consideration would need to be given to the provision of a safe haven.

ACOP 52, ERM 1995 defines a safe haven as a place provided with facilities including an independent air supply to maintain an atmosphere at positive pressure (i.e. greater than the surrounding atmosphere), such that people can wait in safety until rescue arrives. Two types of safe haven are described:

- totally sealed installation, with airlocks and suitable environmental monitoring etc. where people can wait without wearing self-rescuers;
- semi-sealed installation where people can change self-rescuer or wait whilst wearing self contained self-rescuers (self-contained escape breathing apparatus).

ACOP 53 states that safe havens will need to be equipped with a telephone or other communication link so that those inside the safe haven can communicate their presence and messages can be sent from the surface.

ACOP 54 states that any equipment kept in the safe haven should be maintained in accordance with the manager's scheme for the mine and regularly tested.

In 2001, the Health and Safety Commission, through the Deep Mines Coal Industry Advisory Committee, produced *Guidance and Information on Escape from Mines* ISBN 0-7176-2006-9. This states that where there is a possibility that not everyone might be evacuated, the risk assessment (reg. 3 MHSWR1999) will help managers decide what is needed to help those who are trapped to survive until they can be rescued (para.24).

It identifies hazards associated with a fire in the main intake, which would require evacuation of the mine and a risk of dangerous concentrations of products of combustion reaching people travelling out along the main return because the speed of ventilation was faster than their walking pace. Places where escape and rescue risk are increased are identified as:

- single entry headings;
- longwall coal faces with gate roadways over 1000m in length;
- hot and humid roadways;
- steep roadways;
- roadways driven in strata which may emit high-pressure hydrocarbon gases;
- workings where large diesel-powered plant is used;
- mines where there are large amounts of flammable material, for example storage mines; and
- mines using halon or carbon dioxide flood arrangements designed to suppress any outbreak of fire.

Para.41 highlights major factors in influencing the manager's risk assessment as:
distance and ease of travel;
- temperature and humidity of the workings; and
- ability of mines teams to effect a proper rescue.

Appendix 2 Research Report

In 2003, the Health and Safety Executive produced 'Research Report 180 – Use of self-rescuers in hot and humid mines'- ISBN 0-7176-2788-8, prepared for HSE by Mines Rescue Services Ltd.

This report dealt with climatic chamber testing of fit mines rescue workers wearing a variety of filter self-rescuers (FSR) and self-contained self-rescuers (SCSR) in a series of medically supervised tests under hot and humid conditions. In an executive summary, the key results showed:

- In a range of fully saturated atmospheres between 27ºC and 37ºC all test subjects were withdrawn inside one hour of entering the chamber;
- In some subjects, an increase in core body temperature of 2ºC was observed after 30 minutes of exercise;
- During the tests, exceeding a core body temperature limit (38.5ºC) was the predominant reason for withdrawal;
- Subjects self-paced themselves at between 2 to 4 km/h but in all cases, core body temperature continued to rise during periods of exercise;
- Only limited cooling took place during rest periods;
- The average total distance covered during the test runs was 1448m;
- The maximum distance covered was 2350m;
- The minimum distance covered was 590m;
- Total distance covered was influenced strongly by chamber temperature;
- Observed run-out times for SCSR varied (MSA SSR 30/100) from 10 to 25 minutes with equivalent distance covered of between 560m and 1400m; and
- The mean travel speed for the subject group was 3.3 km/h.

References

Criteria for the design of emergency refuge stations for an underground metal mine, Brake DJ and Bates GP (1999), Aus. IMM Proceedings, No.2, 1999, pp 1-7.

Research Report 180 – Use of self-rescuers in hot and humid mines' Health and Safety Executive (2003)- ISBN 0-7176-2788-8, or online at http://www.hse.gov.uk/RESEARCH/rrhtm/rr180.htm

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