REFUGE STATIONS/BAYS & SAFE HAVENS IN UNDERGROUND COAL MINING

Prepared for

The Underground Coal Mining Safety Research Collaboration (UCMSRC) administered by NRCan-CANMET Mining & Mineral Science Laboratories

By

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Report: 3416-001.1
Date: 2003 December (finalized May 2004)

Table of Contents

Executive Summary

This report reviews the application of refuge bays or stations in underground coal mines. The report outlines in turn the Philosophy of Refuge Stations, The Principal Types, International Experience and Regulatory Requirements, Discussion and Summary.

Refuge stations are special places provided in an underground coal mine for use in emergencies and where miners can shelter until it is either safe to escape or until they are rescued. They can be pre-planned and either semi-permanent or temporary or even unplanned (e.g. in the flooding at Que Creek mine in Pennsylvania, USA in 2002).

Originally devised for use in underground metal mines they are increasingly expected to be used in underground coal mines and this has generated some controversy, in the sense that in coal mines, where working sections are usually located in seam they are surrounded by a fuel. Therefore the question can be asked: is it in the best interests of coal miners in a mine emergency, especially in cases of fire or explosion, to stay in the mine in a refuge station.

In metal mines in Ontario, where the procedure for underground fires provides for use of a refuge station the following are required:

- be constructed of materials having at least a one hour fire resistance rating;
- be of sufficient size to accommodate the miners to be assembled there
- be capable of being sealed to prevent the entry of gases
- have a means of voice communication with the surface (Telephone, leaky feeder radio, thru-the-earth radio [PED])
- be equipped with a means of supply of compressed air and potable water, should contain a door opening outward, capable of being sealed air-tight with clay or plastic material. A means of pressure relief through the door must be included with a valve on the inside of the door.

A review of regulations reveals that not all jurisdictions mandate the requirement for refuge stations in underground coal mines, however, in those that do not, best practice is evolving whereby they are used in special circumstances. For example, to provide safe havens or transfer stations where miners can rest and change self-rescuers before proceeding to evacuate the mine.

The use of refuges in coal mines is becoming more common. Typical of South African coal mine refuges, for example, the ideal site is one having a borehole to the surface through which air, water and food can be passed to the mine miners inside. An alternative approach is a dual source of compressed air, although not all mines have compressed air supplies.

The report concludes as follows: “The founding principles of any emergency escape plan in an underground coal mine must be to seek to evacuate the mine with minimum complication and delay. However, for a number of reasons this may not be possible and alternative survival strategies based on the use of safe havens (refuge stations/bays) and self rescuers are required. The use of refuge stations or safe havens can enhance the viability of self-rescuers either by providing a location to change a person-worn short duration self-contained self-rescuer for a longer duration unit or alternatively by providing a separate sealed life support system. As the report by Bird concludes, potentially, the safe haven concept, if developed effectively, has a vital role in establishing a robust emergency survival strategy for use in large hot mines or where there are significant gradients impeding passage out of the mine (Bird 1997)".

1. Introduction

Purpose

This report reviews the application of refuge bays or stations in underground coal mines. Refuge stations are special places provided in an underground coal mine for use in emergencies and where miners can shelter until it is either safe to escape or until they are rescued. They can be pre-planned and either semi-permanent or temporary or even unplanned (e.g. in the flooding at Que Creek mine in Pennsylvania, USA in 2002).

Originally devised for use in underground metal mines they are increasingly expected to be used in underground coal mines and this has generated some controversy, in the sense that in coal mines, where working sections are usually located in seam they are surrounded by a fuel. Therefore the question can be asked: is it in the best interests of coal miners in a mine emergency, especially in cases of fire or explosion, to stay in the mine in a refuge station.

The UCMSRC was asked to research the topic of the use of refuge stations in underground coal mines and to collate information for future reference in a single report. This task arose from specific queries raised by the Participants from the British Columbia Ministry and has resulted in this report. It is intended to be an overview and not a comprehensive treatise on the topic. The report has been prepared for UCMSRC Participants to use as a reference on the subject by Dr. David Forrester, DJFCL, a consultant based in Sydney, Nova Scotia, and active in coal mine safety issues.

The report outlines in turn the Philosophy of Refuge Stations, The Principal Types, International Experience and Regulatory Requirements, Discussion and Summary. The information presented in this report is considered to be representative of the development and application of refuge stations/bays or safe havens. The conclusions drawn and recommendations made are those of the author and do not necessarily reflect those of the stakeholders and Participants in UCMSRC or the authors or regulatory bodies of source material.

Background

It is reported that in the early 1970's a Gold Fields team leader in South Africa stumbled onto the concept of refuge stations, when he saved his team from almost certain death during an underground fire by sheltering them in a development end and opening the compressed air line. Since then refuge bays have been developed and refined and their success has been proved by various incidents where their use has saved lives (JMVS of South Africa 1990). By the mid 1970s refuge stations featured in Mine Safety legislation in some Canadian provinces, by the early 1980s their use in metal mines in Ontario was common, and today most regulatory jurisdictions require their use by law. In provinces where both underground coal and metal mines operate, the advantages of refuges in coal mines are not always as self-evident as in non-coal mines, and this has generated a debate in Canada that continues to today. This report is intended to summarize the various factors and issues to further inform the debate.

Acknowledgements

The author gratefully acknowledges the assistance given throughout the preparation of the report given by UCMSRC members, particularly: Mr Gary Bonnell of NRCan-

CANMET; Kresho Galovich of Quinsam Coal in British Colombia; Dr. Peter Cain, Grand Cache Coal, Alberta; Mr Alan Cramm of Richmont Mines, Newfoundland and Mr Glen Crowther, NB Mining and Smelting, New Brunswick.

2. Philosophy of Refuge Stations

Why Needed

Most underground coal mines today feature annual outputs of over 250,000 tonnes requiring significant planning, and generating a rapidly developing complex of ever-expanding network of underground roadways. Most working sections in underground coal mines therefore involve traveling a considerable distance from the surface, and hence significant traveling time, typically between 15 and 90 minutes, depending on mode of transport and mine layout.

In the event of an emergency, such as a flood or fire, miners may be endangered or trapped. Emergency response planning for such events requires means of safe egress to be provided for miners in the case of an emergency, in particular a mine fire or mine explosion where the mine ventilation can be polluted with harmful gases very quickly. In such situations miners may be in various states of disarray and injury, so provision must be made for both self-escape and aided-escape. Mine emergency response procedures must therefore include self-escape plans, as well as rescue plans, which provide for miners to pass through atmospheres that may not support life.

One of the key factors to consider in this process, is the need for some kind of safe place located along the escape route whereby miners can rest, re-equip, communicate and/or wait for help. These can be preplanned and located at strategic locations, known as refuge stations/bays or safe havens, or they can be constructed in an emergency to meet local specific needs, when they are known as barricades.

Historically, in metal mines, such plans have included refuge stations where miners can shelter in a safe place with adequate provisions and communications until either the danger has passed or they are rescued. A typical scenario may be a diesel vehicle fire which may pollute the atmosphere endangering life but only for a finite time measured in hours before it burns itself out and the atmosphere is safe again. However, a similar fire in an underground coal mine could ignite other material around it such as conveyor belting or even the coal seam itself, in which case the fire could rapidly become a deep-seated one, lasting for much longer possibly days or weeks.

The natural instinct of a miner in such an emergency situation is to ‘run’ and get to safety as fast as possible (e.g. a fresh air base or the surface) and is normally the best thing to do. This is especially pertinent in an underground coal mine, where in the event of fire, the coal seam walls of underground roadways are themselves fuel and may burn for a long-time once ignited. The provision of refuge stations/ chambers/safe havens may go against this general principle as it tempts miners to stay underground. Their use in coal mines therefore begs questions like once men are inside and safe, how are you going to safely get them out and how soon?

Where and When to Use them

There are, however, some circumstances where the use of refuge stations or chambers or safe havens is beneficial. These in turn merit clearly thought-out planned procedures, training and careful technical consideration of related factors such as ventilation, communications, welfare and feeding (LeBlanc - Joliffe 1993). These special circumstances are those which present challenges to the immediate evacuation to the surface of miners. Such challenges include the following:

- long distance from working place to the nearest possible fresh-air base;
- adverse gradients; elevated temperatures;
- restricted egress (e.g. where the main travel-way may be a conveyor roadway and could be a likely seat of a fire); and
- use of shafts where there is no regular personnel transport (e.g. coal winding shafts and empty return shafts)
- the useful time for breathing apparatus, not only for rescue teams but also for miners in terms of the wearing-availability of self contained self rescuer (SCSR) equipment.

With respect to the last point, some longwall districts may involve ventilation circuits of 6.5 km (4 miles) for example in European mines using the single-entry method. The introduction of 60 and 90 minute self-rescuers has helped meet the challenge of such distances but not completely (See equipment available in Table 1, Bird 1997). Special

Table 1 Self Contained Escape Equipment Available (Bird 1997)

1. **30 minute duration**
   a. Fenzy Biocell 1 Start - chemical oxygen unit
   b. Drager Oxy K - chemical oxygen unit
   c. MSA- Auer SSR 30/100 - chemical oxygen unit
   d. Drager SR 30 & 45 - compressed oxygen unit
2. **60 minute duration**
   a. Drager Oxy K plus - chemical oxygen unit
   b. MSA Life-Saver 60 - chemical oxygen unit
   c. CSC SR 100 - chemical oxygen unit
   d. MSA - Auer SSR 90 - chemical oxygen unit
   e. Ocenco EBA 6.5- compressed oxygen unit
3. **90 minute duration**
   a. Fenzy Biocell 90 Start - chemical oxygen unit
   b. MSA - Auer SSR 120 - chemical oxygen unit

Estimating Duration & Travelling Distances for SCSR

Table (ii) may be used as a guideline to determine the duration and distance that it can be reasonably expected that a person can travel when using a SCSR. These guidelines have been established from the 1997 ACARP Project- Number C5039.

The duration of SCSR should be estimated at 60% of their rated duration to take into account body mass greater than 80kg with a heart rate greater than 120 beats per minute. Travel distances should be estimated at 60% of the distance of the distance that 95% of personnel could achieve in good visibility to accommodate for conditions of poor visibility. Condition of roadways, gradient and any obstacles will also have to be taken into account in estimating travel distances.

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 the ability and physiology of those underground. An in-seam trial could be conducted by having a person (who is in excess of 100kg) walking the primary and second means of egress wearing a compressed air breathing apparatus (CABA) to establish your 80% bench mark[2].

Table (ii) - Actual Duration of SCSR's

Conditions	% of Unit Rating	30 min unit	60 min unit	90 min unit
Normal - person under 80kg -heart rate below 120/min	100 %	30 min	60 min	90 min
Normal - person over 100kg - heart rate below 120/min	80 %	24 min	48 min	72 min
95% percentile - unknown weight & heart rate	60 %	18 min	36 min	54 min
95% - Poor visibility - unknown weight & heart rate	36 %	11 min	22 min	33 min

transfer stations may still be necessary at strategic locations where old SCSRs can be exchanged for new ones.

In the early 1980s, in Ontario, as refuge stations increased in number they were integrated into normal underground routine by using them as dual purpose as lunch rooms as well as refuge stations, thus maintaining miner familiarity with location and layout. Location in metal mines is advised in places like winze collars where they can potentially be readily converted for use as an Advanced Air Base in rescue operations (MAPO Draft Handbook of Training). In coal mines with rail transport they should be located at the normal picking up/transfer points and first-aid centres (LeBlanc 1993).

Integration with Mine Rescue

Bird 1997 notes that there is an increasing trend that the Emergency Escape Plan in underground coal mines should not be based solely on use of self rescuers (including long duration ones) and that consideration should be given to the introduction of refuge stations as transfer stations. That is, provision of places where the workforce can shelter in a sealed fireproof structure, or in safe havens, where evacuating staff can rest and change self rescuers. He refers to anecdotal evidence of a recent fire event where 100 men sheltered safely in underground refuges for 7 hours prior to being rescued, confirming the value of the safe haven approach where the scheme is well planned and implemented. Refuge stations have been part of the underground mining scene for many years especially in Canadian and South African Mines. In some countries, however, the provision of such facilities is a relatively new concept. In New Zealand, refuge stations also served as depots for storage of fire fighting equipment and tolls (LeBlanc - McNally 1993).

3. Principal Types of Refuge Stations

There are 2 main types in use, permanent and temporary, each with varying designs and sizes.

Permanent refuges

Metal Mines

Sealed unit or permanent site refuge stations are normally large in size, of substantial construction and serve as a focal point for individuals travelling from a broad area of the mine, often serving the dual purpose as a lunch room. Such units are more appropriately installed in larger mines but are not particularly suitable for rapidly moving working areas of the mine, which is common in most coal mines. The designs of such refuge stations have been well documented particularly in those countries where their use has been reinforced by minimum legislated requirements and guidelines (Ontario Mines Rescue Refuge Station Guidelines, MAPAO Committee, Sept 1990). In metal mines in Ontario, where the procedure for underground fires provides for use of a refuge station the following are required:

- be constructed of materials having at least a one hour fire resistance rating;

- be of sufficient size to accommodate the miners to be assembled there
- be capable of being sealed to prevent the netry of gases
- have a means of voice communication with the surface (Telephone, leaky feeder radio, thru-the-earth radio [PED])
- be equipped with a means of supply of compressed air and potable water
- should contain a door opening outward, capable of being sealed air-tight with clay or plastic material. A means of pressure relief through the door must be included with a valve on the inside of the door.

Typically a man in a confined space requires one cubic metre of air an hour to survive, exceptions being two cases in Ontario. One case involved 29 men surviving for 36 hours in a refuge station 250ft long by 6 ft wide by 6 ft high (9000 cu ft/255cu m), and one in the same mine with only 6 of 8 men surviving for 50 hours in 130 ft long by 7 ft wide by 7 ft high (6,500 cu ft/184 cu m). Survival is prolonged if the occupants rest, although someone should periodically walk around to mix the air. It is advisable for refuge stations and barricades to have airlocks to assist rescuing occupants when the outside atmosphere is still not respirable. The Mine Emergency response plan and procedures should include details on the location, construction, equipping, use of and rescue from refuge stations and barricades.

The MSHA training manual "The Rescue of Survivors and Rescue of Bodies for Metal/non metal mines (MSHA 2206, November 1981)" notes that non-responsive communication with the inside of a refuge station does not necessarily mean that the occupants are dead, they may be unconscious. If there is response then in addition to ascertaining their physical condition/injuries information is needed on use of SCSRs and air supply remaining. Rescue is preferable if fresh air can be advanced to the site, if not then an air-lock (e.g. using canvas flaps) is required to minimize contamination of the air inside and appropriate breathing apparatus supplied to the occupants. The mine rescue 'command centre' would make these decisions.

Coal Mines

The use of refuges in coal mines is becoming more common. The ideal site is one having a borehole to the surface through which air, water and food can be passed to the mine miners inside, typical of South African coal mine refuges. In the 1970 and 1980s in England, there were 12 refuge chambers formally designated (LeBlanc – Joliffe 1993). Some of these were connected to the surface by a borehole providing fresh air, emergency supplies and communication (e.g. Ledstone Luck & Peckfield Collieries in North Yorkshire). They were located in 'blind headings' large enough to accommodate 80-100 persons for 2 days fitted with seats, emergency supplies and a stout door. An alternative approach is a dual source of compressed air, although not all mines have compressed air supplies and consideration of compressor siting is required to ensure their integrity in an emergency situation. Consequently assessment is being made of the possible use of independently powered air supply modules discussed elsewhere in the paper, which provide chemical oxygen source and are equipped with CO^2 scrubbing technologies. In general, refuges for metalliferous and other mines must be designed to have adequate bulkhead fire resistance, while the designs for coal mines must consider also incorporation of precautions against explosion over pressures. Oberholzer (1997) has reviewed biological and structural impacts and considers 140kPa overpressure withstand capacity to be adequate for structures sited away from the face (Brenkley et al 1999).

Typically they are located in a crosscut or blind heading adjacent to the main traveling roadway with thick fire-proof stoppings at each end and are supplied with telephone, compressed air, food and water and set a large number of miners (say 100). Japanese Collieries introduced raised 'sounding boards' outside to identify location in dense smoke (LeBlanc - McNally 1993).

Some longwall faces have very long entries, which could be polluted in case of a fire. For advancing longwall faces a semi-permanent mine survival chamber was planned in Yorkshire but never installed due to premature finishing of the face. This was a steel capsule 4m long to be located in a suitable excavation at the side of a roadway. Connected to compressed air and with its own emergency supplies (including oxygen and nitrogen) it was to be suitable for 6 miners for 2 days (LeBlanc - Joliffe 1993). For retreat faces temporary refuges are now available, see below.

Special circumstances merit special provisions, for example, in some coal mines in the United Kingdom and Australia where sudden outbursts of methane and carbon dioxide can flood a working section. In these cases, the oxygen content in the working sections is temporarily reduced to below 8%, and fresh air stations were installed (e.g. New South Wales in Australia and in the United Kingdom). Typically these involve a compressed air line in the return roadway with breathing boxes placed at regular intervals and a bank of up to 18, close to the working face. The breathing box contains a flexible hose with a valve that automatically opens when the tube is taken out of the box.

Another special provision would be the use by mine rescue teams in some coal mining areas of a special, sometimes dedicated, drilling rig for use in shallow mines (less than 300m). These can drill a large diameter borehole down to a refuge station/chamber and allow men to be withdrawn in a special capsule (Blunt & Joliffe 1976).

Refuge stations are considered to be a technology to enhance emergency response and new equipment and systems are regularly being introduced into the underground coal industry. Some of these relate to technological developments in self contained self rescuers (SCSR), oxygen generators and carbon dioxide scrubbers and have meant that there are a number of different self-escape systems and philosophies that can be implemented. Developments in rescue equipment and methods, also allows for a change in philosophy, making in-seam rescue and emergency intervention possible. By integrating these technologies a more versatile and timely system of emergency preparedness, self escape and aided rescue is developed which greatly increases the probability of underground employees surviving an emergency situation (Bird 1997).

Temporary or Transportable units

Overview

The review by Bird 1997 of temporary refuge stations for use in underground coal mines is comprehensive and is quoted here in full. "The design of temporary havens for underground coal mines requires considerable expertise. The havens have to be practical, to suit rapidly moving working places, yet they must retain the basic elements necessary to sustain life for significant periods of time following a fire or explosion. Based on visibility criteria, Smith and Du Plessis (1998) state that refuge bays should not be further than 750m from the workplace. This would mean in South African terms that refuge bays would need to be constructed at time intervals of between 36 and 185 shifts. Given the impracticability of erecting permanent refuge bays at these intervals intermediate staging points and breathing stations are being evaluated. In some countries, temporary shelters are sited as relay points to assist miners in reaching their permanent safe haven or first aid centre. The nearest shelters are often maintained within 50-100m of the working face and are equipped with compressed air lines and communications. The structures are of vinyl tarpaulin construction with fasteners for sealing the doorway. This form of temporary shelter was largely pioneered in Japan. This concept was proposed to be introduced into UK coal mines in the form of semi-sealed installations, such as canopies or pressurized 'tent-like' refuges, which are erected using a compressed air supply (Forster 1997). Three safe haven designs were being examined in the UK (Evans & Forster, 1997)"(Bird 1997).

Canada's only operating underground coal mine is Quinsam Coal Corporation, near Campbell River, Vancouver Island, British Columbia. The Health, Safety and Reclamation Code for Mines in British Columbia (1997) Part 6, Section 6.16 Requires all underground mines, not under initial adit development or shaft sinking and, where a workplace is more than 300m from a mine portal or shaft station to provide and maintain in a suitable location, a refuge station. See Section 4 below.

Types

Some types of temporary refuge station available commercially are listed below:

Draeger - Escape Chamber: provides protection for 6 people for 4 hours – gas-tight and insulated – oxygen supply, CO2 bonding, cooling and drying of the ambient air, lighting, emergency power supply, monitoring of the air.
Siewic - Rescue Tube: collapse-able containing necessary equipment.
Safety First Systems - Mobile Safety Base: for 6 people for 8 hours - 2-piece construction, skid mounted, heavy wall fibre-glass fire retardant shell, positive pressure, compressed air and water (mine supply), phone, first aid, lighting air cylinders.
Redpath - Portable Refuge Station: for 6-10 people, molded fibreglass fire resistant, skid mounted, communication, first aid, emergency life support, positive pressure.
RANA - ***Refuge One Air Centre*** is a self-contained system that is designed to provide oxygen at controlled rates, and to remove carbon dioxide from the air in an enclosed space. The unit does not depend on the compressed air pipeline, and in an emergency does not require an external electrical source.

Barricades

Traditionally, particularly in non-coal mines, when miners are trapped by fire, where their escape route is cut-off but where the local atmosphere is free of contaminating gases consideration is given to building a 'barricade'. This involves the local sealing off of a 5-10m long section of tunnel/mine roadway (preferably with a valve in a compressed air line available) with a barricade or stopping at each end. Typically barricades are constructed from lumber, lumber and brattice cloth or sandbags (with 'claying' of joints). These are places for miners to rest in awaiting rescue (OML 1982).

Typical Requirements

Although existing provincial regulations do not address the occupancy time and the capacity of mine refuge stations, some basic design rules-of-thumb have been used. A maximum design concentration of three percent carbon dioxide with a minimum of 16.25 percent oxygen at 8 to 24 hours is recommended by Mines and Aggregates Safety and Health Association, Ontario (MASHA) Canada in their "Guidelines for Mine Rescue Refuge Stations". MASHA summarized the various models for dead air space design. All models produce similar results of 5.7 to 6.2 m^3 of dead air space per person to limit the CO^2 concentration to three percent after eight hours. To maintain the same upper limit of three percent CO^2 for a 24-hour period would require three times the dead air space volume (~18 m^3 per person).

In 1993, the Cape Breton Development Corporation carried out a major review of the refuge station issue as their regulations required provision of them (LeBlanc 1993). Amongst other things, they recommended that refuge stations should contain at least the following equipment:- compressed air line; SCSRs; food; potable water; blankets; heat; reading material; lighting; intercoms/telephones; chemical toilets; humidity absorbent; escape plan of the mine, Draeger tubes; spare lamps or lighting; tools; materials (nails, brattice, etc); first-aid equipment and materials; and fire-fighting equipment.

There are now several refuge bay air supply and purification system technology suppliers. These systems can provide an independent oxygen supply and carbon dioxide scrubbing for limited periods of time for groups of 10-20 people or more. Commercial systems include the Canadian Refuge-One Mobile Safety Base or “Tommy knocker”, the South African Mobile Air Rescue Station (MARS) and the Survivair-E Life Support System (Venter et al 1997). These systems are undoubtedly useful but can be compromised by the buildup of carbon monoxide due to air leakage into the refuge. It can be technically difficult to create adequate positive pressure inside the bay and hence research is being directed at incorporating CO scrubbing (Smith & Du Plessis 1998). The development and introduction of refuges or safe havens is also only useful if individuals know where they are located, particularly in low or zero visibility conditions.

For refuge stations equipped with compressed air, such as those commonly found in hard rock operations, design flows should maintain an adequate oxygen supply. It is critical that sufficient air be provided to dilute the CO^2 exhaled in the miner’s breath. MASHA says that flow rates of 50 to 100 scfm (standard cubic feet per minute) per person are required to keep CO^2 levels to less than 5,000 ppm. The use of standard sized (300 ft^3) cylinders is impractical for providing extended protection because of the large volume of compressed air required for dilution.

Mine rescue personnel should be acquainted with basic design considerations for the capacity of a refuge station. Refuge stations should be designed to handle the required number of miners who could be sent to them (Saskatchewan Mine Emergency Response Program - Mine Rescue Manual).

4. International experience with Refuge Stations & Regulatory Requirements

4.1 Canada – province by province

British Columbia

Health Safety & Reclamation Code for Mines in B.C. 1997

s 6.16 Refuge Stations requires refuge stations in underground mines after development where workings are more than 300m from a portal or shaft station. Every underground refuge station shall be: clearly identified, constructed of non-combustible material and of sufficient size to accommodate all persons working in the vicinity; equipped with a supply of air, water and communications to surface, a means of sealing to prevent entry of gas and first aid equipment; equipped with a mine plan clearly showing all exits; and located more than 10m from both explosives magazines and inflammable materials storage.

In Canada's only operating underground coal mine in 2003/4, Quinsam, on Vancouver Island in British Columbia, they comply by using a portable refuge station on skids. It is a double-door, made of steel without fire resistance and insulation, with a volume of $18m^3$. It is equipped with oxygen, radio communication, telephone, sealant, first aid kit, survival kit, water, portable toilet. Their evacuation procedure is simple: First - get out of the mine; second, only if immediate evacuation from the mine is not possible, use the refuge station. British Columbia has a Mine Rescue Manual, which details procedures for Refuge Stations and their Use and Alternate Emergency Refuge.

Alberta

OHSA Mine Safety Regulation 292/95 December 21, 1995

s 54 requires refuge stations in all mines. A refuge station must have water, air and an effective communication system to the surface and be separated from adjacent areas such that gases can be prevented from entering.

Saskatchewan

Require refuge stations in underground mines by regulation.

Manitoba

Mines Act & a Regulation governing the Operation of Mines 254/73 Chapter M160 March 1977

s 8.03 requires refuge stations in all mines if the Chief Mining Engineer deems it necessary. They shall be clearly identified and of sufficient size and have air water and surface communications and be separated from adjacent areas such that gases can be prevented from entering.

Ontario

Required in all mines under regulation (*Ontario R.R.O.1980,Reg.694 s 24*)

Quebec

Require refuge stations in underground mines by regulation.

New Brunswick

Require refuge stations in underground mines by regulation.

Nova Scotia

N.S. Reg. 153/2003 - Underground Mining Regulations made under Section 82 of the Occupational Health and Safety Act

Require refuge stations in underground mines by regulation.

146 (1) An employer must construct, inspect, and maintain a refuge station every 300 m underground in an active working if a person has to travel more than 500 m to reach
(a) the mine exit; or
(b) if a shaft conveyance is used to reach the surface, a shaft station.

Sections 147 to 153 pertain to construction and location of refuge stations, air supply in refuge station, equipment in refuge station, requirement for refuge station procedures, procedures posted at refuge station, permitted uses of refuge stations and monthly inspection of refuge stations.

Note: Nova Scotia regulations will be edited in the future to remove requirements for refuge stations in underground coal mines.

Newfoundland & Labrador

Require refuge stations in underground mines by regulation.

Federal

The Federal CBDC Regulations 1990 require provision of refuge stations

4.2 USA

US Federal regulations (30 CFR 75.1500) allow but do not mandate the use of refuge chambers in underground coal mines. Regulations also require that all persons in an underground coal mines to be supplied with a 60min SCSR (30 CFR 75.1714). The USBM developed Guidelines for Rescue Chambers. From 1940-1980 their records show that of 1710 miners in emergencies faced with the decision to barricade or not, 404 died (24%). Of the 1710, 222 chose to barricade and of those 95 died (43%). Of the 1588 who chose to escape 309 died (20%) (LeBlanc 1993)

4.3 United Kingdom

Regulations do not require refuge bays but large collieries with complex layouts and specific restrictions adopt them, with bore-hole access to the surface where possible for provision of fresh air power communications and emergency supplies (LeBlanc 1993).

4.4 Australia

New South Wales

The Coal Mining Regulations Act 1982 No.67 and Regulations (upto 1994) was examined and no mention of refuge stations was found.

Queensland

Coal Mining Safety and Health Regulation 2001 s 168-169 require provision of a safety and health management system for self-escape, to be developed through risk assessment, including a standard operating procedure and consideration of a number of factors including “the number and location of (SCSR) change-over stations and refuges”.

4.5 South Africa

Installation of refuge bays for all mines was made compulsory in late 1986, following the Kinross disaster earlier that year. South African Coal Mines tend to be relatively shallow (less than 300m) and typically their refuge bays have a bore-hole connection to the surface through which air, water and food can be passed to the mine miners inside.

4.6 Japan

Refuge stations required under Coal Mine Safety Regulation March 1994 Article 70-2 (Shelter – rescue activity during disasters). Shelter facilities are to be located near working places with air supply and communication to the surface, miners must be instructed on location and use of shelters.

4.7 Germany

Generally forbidden by regulation and practice whereby mine layouts are designed such that each working section is less than a 90 min walk to the nearest fresh air supply and 90 minute SCSRs are used throughout. Where, by exception, this is not possible then refuge stations are used.

5. Discussion

The kernel of the dilemma of use of refuge stations in underground coal mines is as follows: the natural instinct of a miner in a disaster situation is to run and get to safety as fast as possible and this is normally the best thing to do, where in the event of fire, the coal seam walls of underground roadways are themselves fuel and may burn for a long-time once ignited; however, the provision of refuge stations/ chambers/safe havens may go against this general principle as it tempts them to stay. Their use in coal mines therefore begs questions like once men are inside and safe, how are you going to safely get them out and how soon?

One of the key factors to consider in this dilemma, is the need for some kind of safe place to be used as a transfer station. Located along the escape route, it is a place where miners can safely rest, re-equip, communicate and/or wait for help. The key to addressing this dilemma, is that, like most issues in mining, is to look at it on a case specific basis. That is, on a mine-by-mine, district-by-district basis, where the distance to travel and likely travel times in fire conditions can be considered. In this case, if miners cannot escape to fresh-air using SCSRs in one attempt, then consideration must be given to providing safe places to rest and re-equip – transfer stations or 'staging posts'. It is steadily becoming understood worldwide that in the large complex underground coal mines so common today, such safe places or safe havens, that is refuge stations, are have a meaningful role to play and consideration must be given to incorporating them in emergency response plans.

Research is ongoing into various aspects of mine emergency response, including refuge stations. One area that has received attention is how to ensure that miners escaping in dense smoke do not pass-on-by or 'miss' the refuge station, as several tragic cases have occurred where miners have perished having traveled past the refuge station, not being able to locate it. Since then, various techniques have been developed to help prevent reoccurrence, that is to improve the visibility of or warning of the proximity to the location of a refuge station in dense smoke. In particular, current research includes special luminous paint, audio, and physical techniques. That developed in Japan is of particular interest – the use of raised boards on the floor outside the refuge station, not only is the floor raised but also it is hollow making a different sound – known as 'sounding boards'.

A further aspect to this dilemma is where to safely locate conveyor belt systems, a major fire risk. In coal mines, generally long lines of belt conveyors are used to transport the coal to a vertical shaft or to the surface up slope-shafts. These are a significant and probable source of fire producing harmful smoke, which will contaminate and pollute air and working sections downstream. As such their location is an important consideration to emergency response and exit planning. There are typically three locations:

- Intake airways – this means that any conveyor fire contaminates all the fresh air to the mine inbye of the source of fire.
- Leakage intake (a separate roadway often parallel to the main intake) – if well maintained and ventilation doors are kept tightly closed, this diverts smoke-contaminated air along the leakage intake and directly into the return airway.
- Return roadway – this means that smoke-contaminated air flows directly down the return roadways and out of the mine with minimal contamination of fresh air.

Consideration of the most appropriate location must be done on a mine specific basis where the pro's and con's can be weighed for each individual operation.

6. Summary

The founding principles of any emergency escape plan in an underground coal mine must be to seek to evacuate the mine with minimum complication and delay. However, for a number of reasons this may not be possible and alternative survival strategies based on the use of safe havens (refuge stations/bays) and self rescuers are required. The use of refuge stations or safe havens can enhance the viability of self-rescuers either by providing a location to change a person-worn short duration self-contained self-rescuer for a longer duration unit or alternatively by providing a separate sealed life support system. As Bird concludes, potentially, the safe haven concept, if developed effectively, has a vital role in establishing a robust emergency survival strategy for use in large hot mines or where there are significant gradients impeding passage out of the mine (Bird 1997).

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