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Mine Refuge Chamber Summary

Related Reports - Volume II

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Department of Health and Human Services
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Office of Mine Health and Safety

NIOSH

REFUGE BAY RELATED DOCUMENTS

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DOCUMENT 1

SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

Final Project Report

Title:	ASSESSMENT OF REFUGE BAY DESIGNS IN COLLIERIES
Author/s:	J W OBERHOLZER
Research Agency:	CSIR – DIVISION OF MINING TECHNOLOGY

Project No: COL 115

Date: JANUARY 1997

EXECUTIVE SUMMARY

The original output of this project was directed at reassessing the survival strategy following colliery explosions and fires. With regard to explosions, problems were experienced with delivering the outputs with regard to strength requirements for refuge bay bulkheads. These problems were resolved during a special meeting held early during 1996 when the scope of the final output was redefined to focus on the characteristics of the explosions that refuge bays could be subjected to in the underground environment and how (it is anticipated) they would react to these explosive forces. By comparing present practice with these requirements, an indication of the present suitability of structure could be determined.

In assessing the characteristics of explosions use was made of experience at experimental mine and explosion gallery facilities throughout the world. To determine the effects explosions have on structures and human beings, use had to be made of experience gained in the fields of commercial and military usage. Information relating to the construction of refuge bays on mines was obtained from codes of practice and discussions with staff from the industry.

It was found that the most probable explosion forces that had to be catered for would lie in the order of 140 kPa pressure. It is, however, not anticipated that the refuge bay bulkhead would require this strength, at the practical distances it would be placed away from the face. By using the 140 kPa specification the possibility of a lower order coal explosion would also be catered for. If the strength requirements were increased above this specification of incidence of fatalities at these higher pressures would be so severe that very few or no survivors would be left to make use of the refuge bay.

The refuge bay designs on the mines are more than adequate in the event of fires occurring. It is, however, doubtful whether the strength of these structures, as evidenced by the codes of practice, would withstand an explosion. What is of greater importance, however, is that the distance allowed between the face and the refuge bay make the possibility of workers reaching the refuge bay in condition of low visibility almost non-existent. To establish refuge bays at the intervals required to cater for these conditions would place onerous requirements on the mines concerned. The need for a survival strategy that incorporates an intermediate place of safety is indicated.

From the findings of this report it is thus recommended that a strength requirement for designing refuge bay bulkheads of 140 kPa is used. To enable these bulkheads to be tested, it is further recommended that the establishment of a local test facility, where local designs can be tested, be investigated.

It is also recommended that the use of an intermediate safe haven be introduced as part of a revised rescue strategy.

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1 INTRODUCTION

This report, which deals with aspects of the design of refuge bays, is directed at members of the mining industry, as well as the members of the SIMRAC system. The purpose of the report is to give a rationale to determine the most probable forces that a refuge bay would be subjected to, and from this develop proposals which can be used in the design of these structures. By comparing the determined requirements with the specifications of refuge bays presently being used in underground mines, shortcomings in the system can be identified and possible solutions proposed. This report also addresses the construction of refuge bays, with specific reference to the construction method of bulkheads that are used to construct refuge bays.

Finally, further action, as well as work based on the identified shortcomings, is proposed. Although specific details, regarding the effects of explosions in the underground environment and the methods to cope with them (due to the uncertain manner in which they occur), cannot be given, the report, nevertheless, does address the issue to the extent that decisions can be made or further work formulated.

1.1 Scope of the Report

For various reasons the scope of this report was changed by the sub-committee controlling its progress (SIGEH).

The revised requirements for this project can be formulated as follows:

To investigate the characteristics of methane and coal dust explosions in underground coal mine workings.

To review the effect of such explosions on typical underground structures.

To list the existing practices being used by mines to construct refuge bays. Specific attention will be given to methods of construction, placement of bays and the type being used.

To determine the ratio between the required thickness and the area of a bulkhead to cope with the explosion characteristics as determined in the first part of this study.

These issues were addressed through relevant literature, as well as through consultation with the experts in the field and in-house experience in dealing with rescue and escape strategies. Although not contained in the scope, information in the literature that is useful in devising escape strategies is also included in this report.

1.2 Constraints

Though the scope of the project required the determination of the effects of typical coal mine explosions on underground structures in order to quantify these issues to a high level of certainty, it was found to be impossible. It became evident that the nature of underground explosions is so diverse that is almost impossible to predict the circumstances under which they would occur, and, therefore, the effect of the explosion. In the light of the uncertainty about the actual explosion, coupled with the effects caused by the underground geometry, it becomes even more difficult to predict the forces that a structure will have to withstand.

Although investigated in theory, on the whole overseas testing of bulkheads has mainly consisted of using trial and error methods[19,37] where the bulkheads, that have been designed, have been tested using actual explosions in test mines or galleries. By nature these test explosions were a simulation of what could occur, but experience at these galleries found that actual explosions can often not conform to the predictions and have lesser or more severe effects than what was anticipated.

It was further indicated in the study that it is almost impossible to do a theoretical design of a bulkhead unless very complicated and expensive finite element simulations were conducted. The results of these tests, however, would always be constrained by the inability to describe the explosion in the required detail. Even after such analysis has been conducted, actual testing of the seal is then still required. In the light of the above, and to effect as large a contribution as possible, use has been made of case studies and empirical experience worldwide to illustrate principles.

Where possible, techniques to improve the design have been provided but the exact effect of these techniques on the bulkhead withstanding a specific explosion could not be quantified.

2 EXPLOSIONS IN COAL MINES

2.1 The Characteristics of Explosions

An explosion occurs as the result of three components acting together. These three components are a source of initiation, an oxidizing agent (usually the air), and, thirdly, fuel. In the case of coal mines, this fuel is either methane or methane combined with coal dust. As legislation in all coal mining countries requires the inertisation of this coal dust, it can be assumed that when a coal dust explosion occurs something in the precautionary measures went wrong.

To enable an understanding of explosions and their effects to be quantified, information regarding surface explosions, as well as explosions occurring in the underground environment will be used. In many cases this information can only be found in the literature relating to commercial or military explosives or even the effects of nuclear weapon blasts.

Explosions are usually high speed decompositions of solids or liquids into a gas (In the case of methane the gas is oxidised into other gases), with the space previously occupied by the explosive or fuel, i.e. after the explosion, filled by the resultant gaseous mixture which would be at a high pressure and temperature.

Principally two types of explosives will be considered.

The first type of explosives are high explosives which detonate rapidly after the chemical reaction has been triggered by a mechanical shock wave that travels through the explosive. A typical high explosive is TNT, one gram of which can release 1120 calories of blast energy and at the moment of detonation generates pressures of approximately 6,900 MPa within the initial gas generated[1]. As the energy of these explosives is released so quickly and the pressures generated rise so quickly, high explosives possess a characteristic called brisance which is the ability to shatter.

Other types of explosives, like explosive gases, dusts or gunpowder, release their energy at a slower rate either by burning or deflagrating, and, therefore, do not usually posses the brisance characteristic. It should be noted that when these slower burning explosions detonate, brisance could occur, however, it can be assumed that explosions of methane/air/coal dust mixtures so seldomly go into a detonation phase that the occurrence of brisance can be discounted.

When an explosion occurs the high pressure that is generated is transmitted to the surrounding air and propagated as a shock wave that travels out radially from the point of ignition. The idealized shock wave created by an explosion is a steeply climbing pressure that rises to its maximum value after which it decays over a longer period to a minimum that is less than the previous ambient pressure. In Figures 1, 2, and 3 examples of such wave forms are presented.

In characterizing explosions the static pressure is almost always used as an indication of the strength of the explosion. It is usually measured with a transducer that does not disrupt the shock front or gas flow and the sensing surface is oriented at right angles to the direction of travel of the blast wave.

The peak pressure, duration of the initial positive pressure phase, as well as the velocity of the shock wave are all functions of the size of the explosion. The size of the explosion is in turn a function of the amount of explosive fuel available. The medium in which the explosion occurs[*1] also plays a role in the manner the shock wave is propagated, eg. in water a wave will travel significantly faster due

[*1] Although the medium through which the explosion travels is always air in mines, the explosive energy attenuation in water is so much less, due to the incompressibility of water, that the lethal radius of an explosion is about three times larger in water than in air.

to the incompressibility of the medium. For the purposes of this study only effects in air will be considered.

The medium that the explosive wave has to travel through has an attenuation effect and, thus, the distance that the wave travels from the explosion also has significant effect on the forces encountered by any object(2). This pressure wave travels much faster than the actual flow of hot gases expanding away from the point of ignition, hence the pressure wave generated by an explosion invariably precedes the flame front.

2.2 The Characteristics of Explosions in Coal Mines

2.2.1 Types of explosions

Two aspects need to be considered in determining the type of explosion that could occur in a coal mine. The first aspect is the fuel involved with the explosion. The fuels usually involved with coal mine explosions are methane and coal dust. It should, however, be considered that although methane explosions cannot be fully countered, the occurrence of a coal dust explosion, in the light of the preventative measures prescribed and used, cannot be accepted as an acceptable norm on which design decisions should be based.

The second aspect to consider is the type of explosion or the explosive mechanism that has occurred.

The manner in which the fuel for the explosion occurs has a significant, if not overriding effect, on the resultant explosion. The volume of the fuel in the form of a gas-air body affects the static explosion pressure that develops. In the Lake Lynne experimental mine which is an experimental facility run by the Pittsburgh Research Centre (formerly part of the United States Bureau of Mines), tests have been conducted with 7,4 m^3, 36,8 m^3 and 53 m^3 volumes consisting of a 9,5 % mixture, with static pressures of 63,280 and 368 kPa, respectively, obtained at the face. The flame length was approximately five times the length of the original volume containing the methane -air mixture(3). In a coal mine section the most probable fuel for an explosion would be from an accumulation of methane, which, if ignited, causes an explosion which would grow outwards from the point of ignition until the side of the roadway is reached, after which the explosion progresses along the roadway. If the methane is the only fuel the explosion will increase until the fuel or oxygen is consumed after which it would die out.

In the event of a methane ignition or explosion igniting coal dust the whole picture is changed as the coal dust adds more fuel for the explosion and, instead of a decreasing explosion, the addition of coal dust could actually increase the intensity of the explosion as it progresses.

If the gases are subjected to turbulence or mixing during the explosion, the pressure achieved by the explosion is also increased. In tests conducted to assess the strength of seals, Weiss, Greninger and others[4 5 6] specify that to achieve the required 20 psig (140 kPa) pressure wave it was necessary to create turbulence in the methane-air chamber by the use of water filled barrels.

An acceleration of the flame is brought about either by turbulence (from the walls of the structure or from obstacles to the free expansion of the gases, like equipment) or by pressure piling as the flame progresses down the tunnel. This acceleration could lead to more rapid combustion, leading to either a rise or maintenance of pressure[7].

Pressure piling is an additional increase of pressure in the main body of exploding gases brought about by the accelaration of gases from the back and the constraining of the gases at the front caused by the tunnel walls as well as a reluctance of the gases in front of the pressure wave to move due to resistance from the sidewalls or other obstructions.

The explosion type

In assessing work done at the USBM, Maser *et al*[8] classified explosions that could happen in the underground coal mine environment into three groupings.

1 Simple deflagrations wherein the reaction zone travels away from the ignition zone at constant velocity (significantly less than the speed of sound, e.g. at about 1-2 m/sec).

2 Accelerating deflagrations where the reaction zone accelerates through the unburnt gas. As this causes a distortion of the flame front the process is self accelerating. The zone of acceleration creates pressure pulses which travel at the speed of sound in ambient air. The feature of the shock wave is the increase in speed and almost instantaneous rise-time. The pressure peak or maximum pressure is greater than that of the simple deflagration.

3 Detonations occur when the shock wave and reaction wave move together. This explosion is characterized by a high pressure (1 MPa) and a very short duration, as the shock wave travels at a speed greater than the speed of sound in the ambient air. Detonations could occur in very long (>60 roadway diameters) or confined gas zones. It is, however, felt that these are unlikely to occur in the underground environment. If, however, a gas is pressurized to a high level, as could be the case in ideal wave reflection conditions, a detonation in the gaseous explosion could occur. Under these conditions it has been found[9] that the speed of the explosion could rise to between 2100-2400 m/s with respective pressure increase of between 0,5 and 90 MPa.

Cybulski[10], in a similar fashion, classifies explosions into the categories presented in Table 1.

Table 1 TYPES OF EXPLOSIONS CONNECTED WITH CHEMICAL REACTIONS

Name of the process	Velocity	Mechanism of the heat transfer
Thermic	Very slow	Conductivity, convention.
Deflagration	From low to high	Conductivity, convention, radiation
Detonation	Very high (>1000 m/s)	Hydrodynamic

In Figure 1 the relationship of pressure and time for the three types of explosions are presented in idealized form, and in Figure 2 the progression of an explosion in the Buxton tunnel is presented. Figure 3 shows an example of the progression of an methane explosion in the GP Badenhorst Tunnel, while Figure 4 shows how all of the characteristics of the explosion are changed when coal dust is part of the fuel.

In Figure 3 points a_1 and b_1 show the pressure of the wave as it travels along the tunnel. In the 200 m length there is no real change. In Figure 4 it is evident how the initial pressure (a_2) caused by the methane is much lower than that caused by the coal dust igniting (b_2). When the flame has progressed down the tunnel only then is the maximum pressure obtained (c_2).

2.3 Aspects Influencing the Force of Explosion

The prime characteristic of an explosion is the speed at which the reaction occurs. In a coal mine, the explosion can also be characterized by the speed of the expanding burning gases, the speed at which the pressure pulse travels down the roadways, the increase in static pressure and the temperature that the gases reach.

Although the severity of an explosion is traditionally described by the results or damage caused, it has been proposed that severity can also be indicated by a combination of the pressure and the time of the explosion. If the explosion is represented as a Displaced Cosine Pressure - time graph, the severity can be indicated by the area falling under the graph[11].

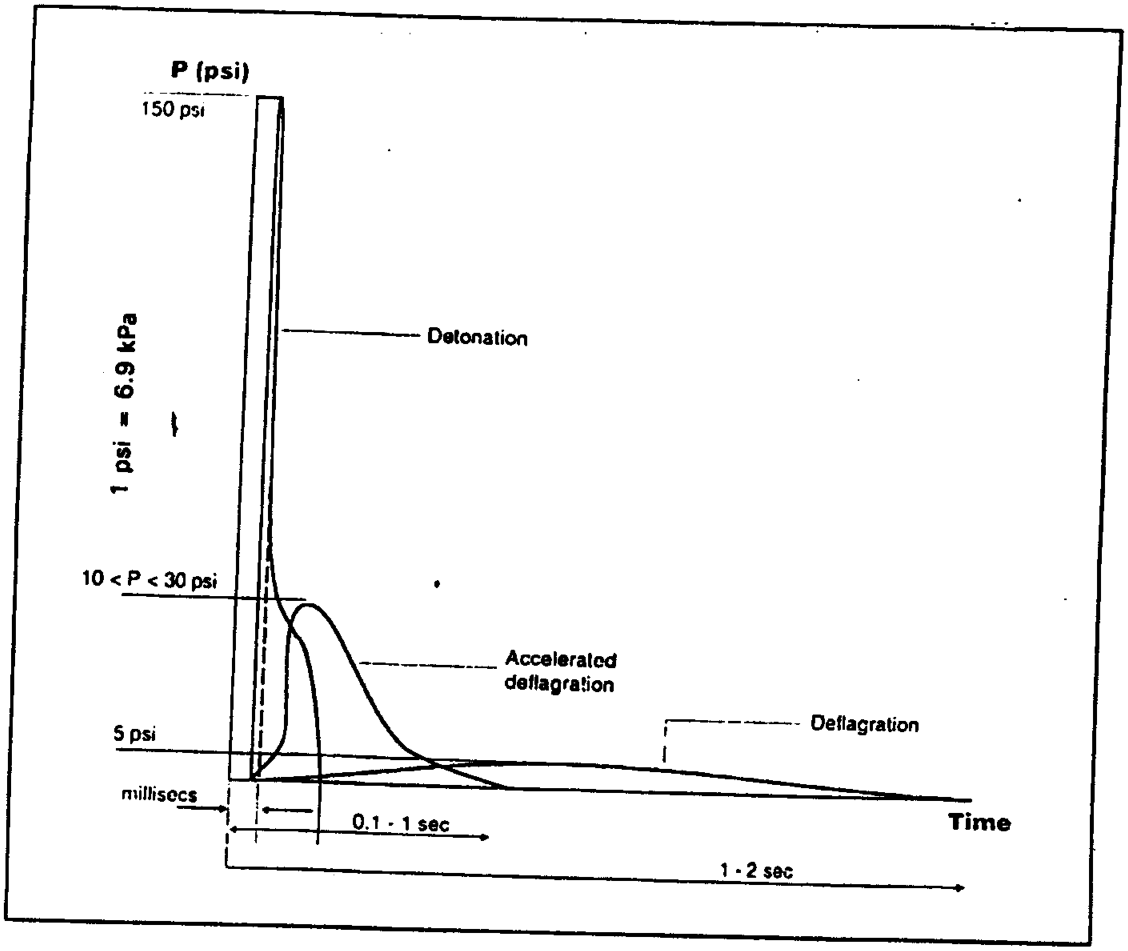

Figure 1 <u>TIME-PRESSURE GRAPHS FOR DIFFERENT TYPES OF EXPLOSIONS</u>

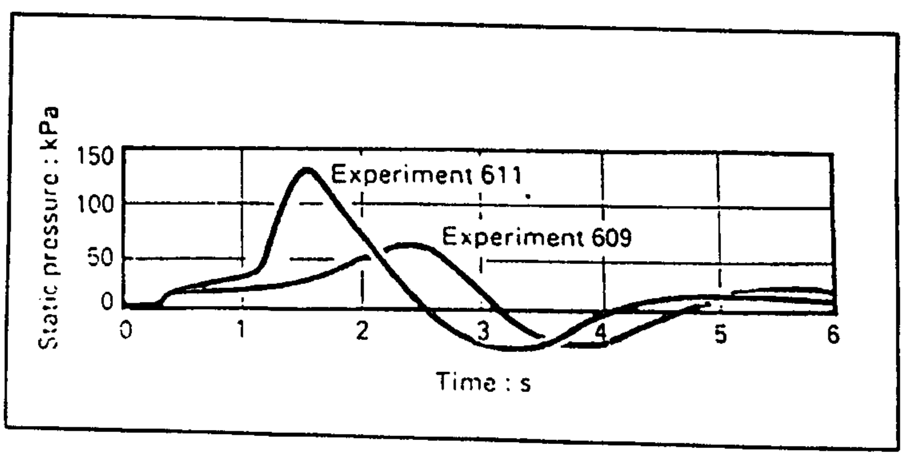

Figure 2 <u>TIME-PRESSURE GRAPH FOR A TYPICAL EXPLOSION IN THE BUXTON FACILITY</u>

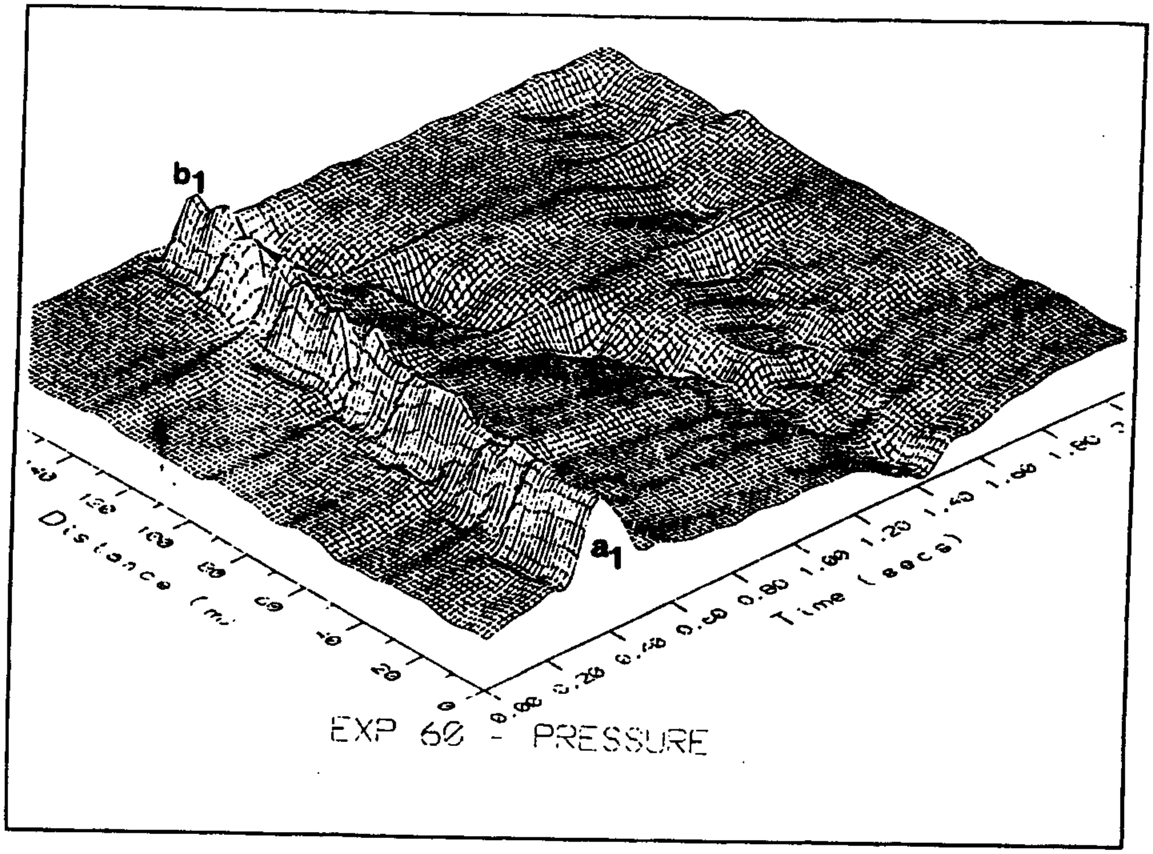

Figure 3 TIME-PRESSURE-DISTANCE GRAPH OF A METHANE EXPLOSION
(Results obtained at the Kloppersbos Test Gallery)

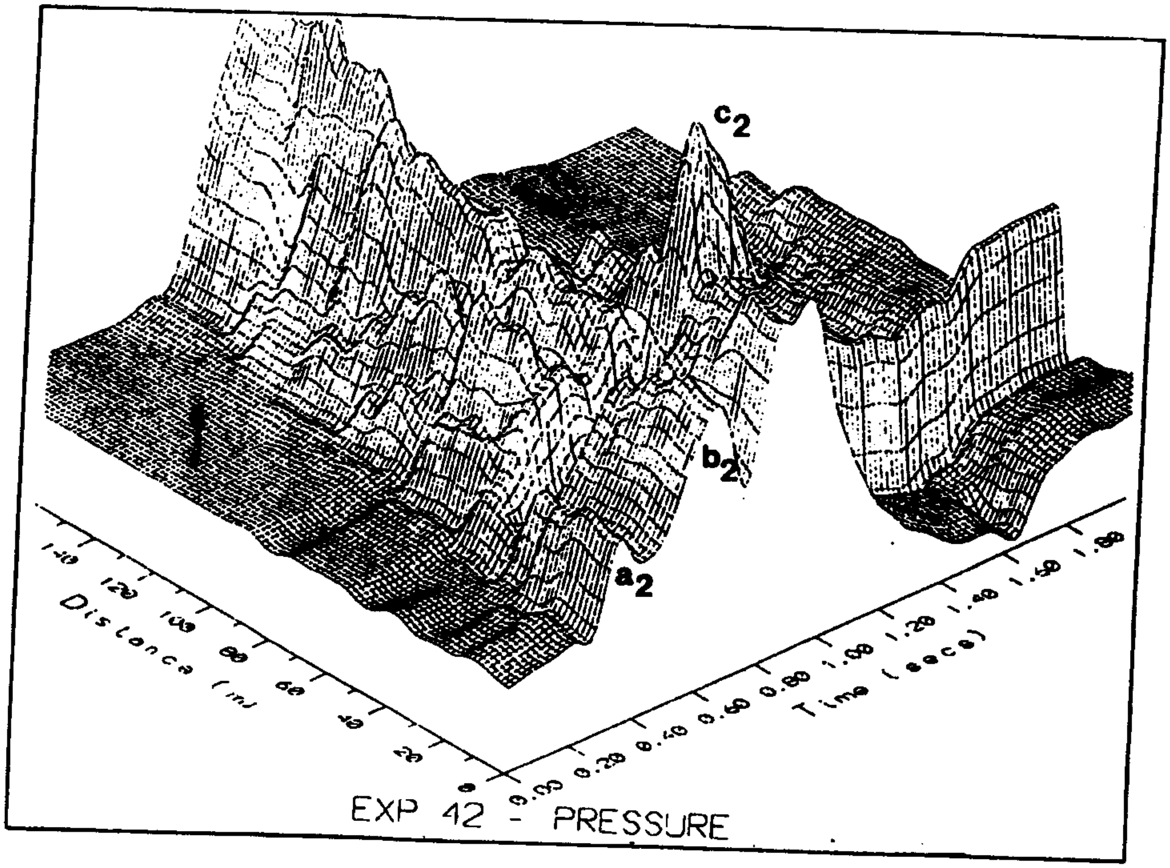

Figure 4 TIME-PRESSURE-DISTANCE GRAPH OF A COAL DUST EXPLOSION INITIATED BY A METHANE EXPLOSION
(Results obtained at the Kloppersbos Test Gallery)

2.3.1 Amount of explosive fuel

In air the peak pressure reached by the explosive products is proportional to the cube root of the charge mass[12] of the explosive.

Work done by Nagy[17] indicated an increase in the explosion intensity as the volume of methane increased. Figure 5 compares methane explosions where doubling the amount of explosive (methane gas) lead to an increase of almost two and a half times the pressure. Apart from the increase in pressure the speed of the explosion increased.

The experiments were conducted in a gallery where the cross-section was constant and the contained volume of gas/air mixture was thus proportional to the length of the chamber of gas. The amount of fuel was proportional to both the concentration of methane and the volume of the gas/air mixture.

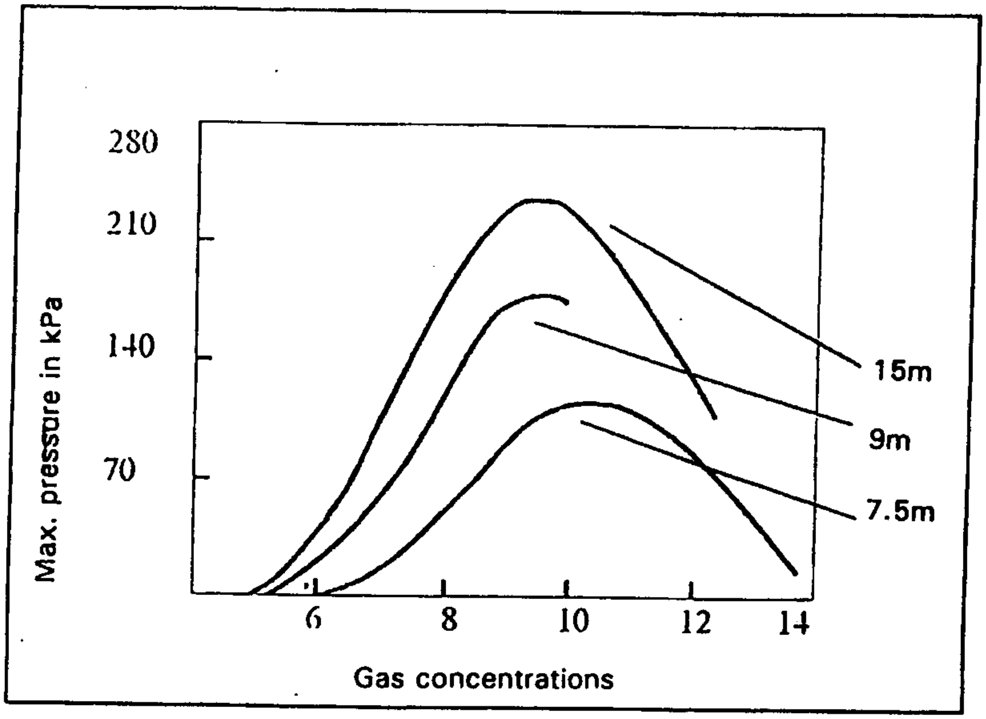

Figure 5 EXPLOSION PRESSURE 15 m FROM FACE PRODUCED BY IGNITION OF GAS-AIR MIXTURES IN 7, 5, 9 AND 15 m ZONES

2.3.2 Containment

Uncontained the pressure of a gas, or diffuse reactant, will not exceed 16 psi (112 kPa). The reason for this is that the speed of the reaction will not exceed the speed of sound which means that the positive wave cannot exceed the absolute negative pressure (an Absolute Vacuum which is 16,7 psi (116,9 kPa) at sea level[13]).

When the explosion is contained it results in raising the effective pressures and prolonging the effect of the explosion. The maximum pressure that can be attained with the optimum concentration of any gas or dust completely filling any closed space (with complete combustion within the space) is about 700 kPa. Changing the room size would only effect the time the perimeter of the exploding gases take to reach the walls of the space. Smaller contained volumes would reach this maximum level quickly whereas larger volumes would take longer to reach the peak pressure[7].

The issue of containment is important in the design of bulkheads for refuge bays, as well as for the construction of seals. When a seal is erected to close off an old area, it contains the old area. In the event of an explosion occurring behind the seal, the pressure generated will, ultimately, be determined by the amount of fuel behind the seal and the volume to which the explosion expands. If the volume behind the seal and that of the explosion is similar, then the explosion will become contained, with a significant expected increase in pressure on the seals.

A bulkhead for a refuge bay is not subject to the same conditions as it is not in a contained condition (except if the explosion starts in the bay itself, the probability of which is neglectably small).

As the chances of an explosion originating at the face is greater than at the bulkhead, the bulkhead would be subjected to a explosive wave and overpressure that has already diminished significantly.

Thus care has to be taken not to accept the same strength requirements for bulkheads as demanded for mine seals, as they have been designed for significantly more adverse conditions.

The maximum pressure developed by a dust explosion can best be measured in a 1 m^3 vessel. Although it has been found that the pressure developed is not a strong function of vessel size, the pressure developed in the Hartmann vessel is in the order of two to three times lower than in a 1 m^3 vessel. As the dust concentration is seldom optimum in practice, the 1 m^3 vessel usually gives enough of a margin of safety so as to give representative values for contained explosions[18]. It has been found that by using this technique, pressures, ranging from 500-600 kPa for carbonaceous dusts and up to 1,3 MPa for aluminium dusts, could be generated. Using the same method methane had a maximum pressure of 750 kPa.

2.3.3 Size of the initiating energy for the explosion

The influence of the size of initiating energy on the progression has been indicated by both local and overseas research. In the event of a larger initiating energy source the explosion progresses at a faster rate.

Cybulski[10] noted that an increase in power of the initiating explosion from 200J to 1000J causes the static pressure to increase from 45kPa to 70kPa. In latterday tests in the 20m tunnel at Kloppersbos[48] it was found that there was almost no increase when the detonators strength was increased. This could possibly be due to the relatively small amount of methane in the tunnel volume or the unconfined nature of the explosion.

In the underground environment the probability of a frictional ignition is higher than other sources, e.g. electrical sparking or the misuse of explosives. When an ignition is caused by the friction between the cutting picks and rock then such an initiating event can be considered to be of low energy, which means that explosions resulting from this would have a lower severity than those created in test facilities where chemical or electrical igniters are used.

However when such a methane explosion involves a large amount of methane and is allowed to expand, it can serve to create enough of an initiating event to ignite coal dust even when the amount of inert material is relatively high. (Cybulski refers to an explosion that devastated a mine even when the amount of inert material exceeded 80 %.)

2.3.4 Presence of suppressants

The presence of suppressants can reduce the effect of an explosion. Cursory work done in the USA[17] has indicated that the effects of even a methane explosion can be reduced significantly by the presence of stone dust.

The presence of stone dust, at the legal requirements, stops a methane explosion from progressing to being a significantly more severe coal dust explosion.

According to Cybulski[10] and confirmed by Du Plessis[49] the stone dust has the following functional action.

It acts as a heat sink

It screens the radiation from combustion processes between coal particles.

The stone dust particles obstruct the diffusion of oxygen and combustible gases.

Although not implemented in South African mines as yet, the use of an active suppression system would reduce the effects of a methane ignition even if it does not manage to douse such an ignition completely.

2.3.5 Release of pressure - distance from the source

The highest static pressure is obtained at the face of the entry, and the maximum pressure decreases as the distance of the gas body from the face increases. No matter where the body of gas was located the highest pressure recorded is at the face, and this pressure is usually two to four times higher than the pressure 150 m from the face[3].

Cook[1] gives the peak pressure at any distance as a function of the initial charge mass and the distance from the explosion. The following formula describes this:

Peak pressure = $A/z + B/z^2 + C/z^3$

where spread of the explosion, z, is equal to

$z = R(\text{distance})/Q^{1/3}$

and Q is the charge mass of the explosive.

It has been found that for an explosion in the air, the last term of the equation (C/z^3) is dominant very close to the explosion (<10 charge radii), with the peak pressure varying as the inverse of the distance cubed. At further distances the first term starts to dominate with the peak pressure now varying as the inverse of the distance from the explosion.

In practice this means that close to the explosion there is a significant drop in pressure, while further out from the explosion there is a lower rate of pressure drop.

This is borne out by the damage caused to structures and humans close to the explosion, whereas only a relatively small distance away, very little or no damage occurs.

Referring to work done by Maser[8] the effects of intersections and turns were also determined. It has been found that the shock wave is attenuated by a factor 0,80 for every intersection passed. Thus, if three intersections have been passed then the peak pressure of the wave would have been halved. This aspect will result in lower pressure being experienced a distance away by bord and pillar sections than in the case of long walls, where the entries are long and straight.

This is of great relevance to the present study since these results were obtained as part of a study to determine the optimum design of seals in underground roadways.

From Figure 6 it is evident that there is almost a halving of the pressure over a distance of a bord of 150 m. This decrease is more noticeable in the higher volume explosion and higher initial pressures: When the initial pressure is lower there is less of a pressure reduction. From this graph it is also evident why it was difficult to obtain high pressures to test seals at distances greater than 100 m. This is of great significance for determining strength requirements as the graph would tend to indicate that only massive methane explosions would be able to reach pressures in excess of 140 kPa at distances greater than 150 m from the face.

In Appendix G a summary is presented showing further ranges of explosion characteristics as used for testing seals.

In assessing the pressure reading from various sources it was observed that the maximum pressure peak obtained by controlled methane air explosions was 30 psig (210 kPa). It was also noted that the duration of the pressure pulse was in the order of approximately 0,25 of a second.

This aspect is borne out and reported by Nagy[3] in work which determines the way the maximum pressure is reduced by the distance travelled away from the point of explosion. In Figure 6 this relationship has been presented.

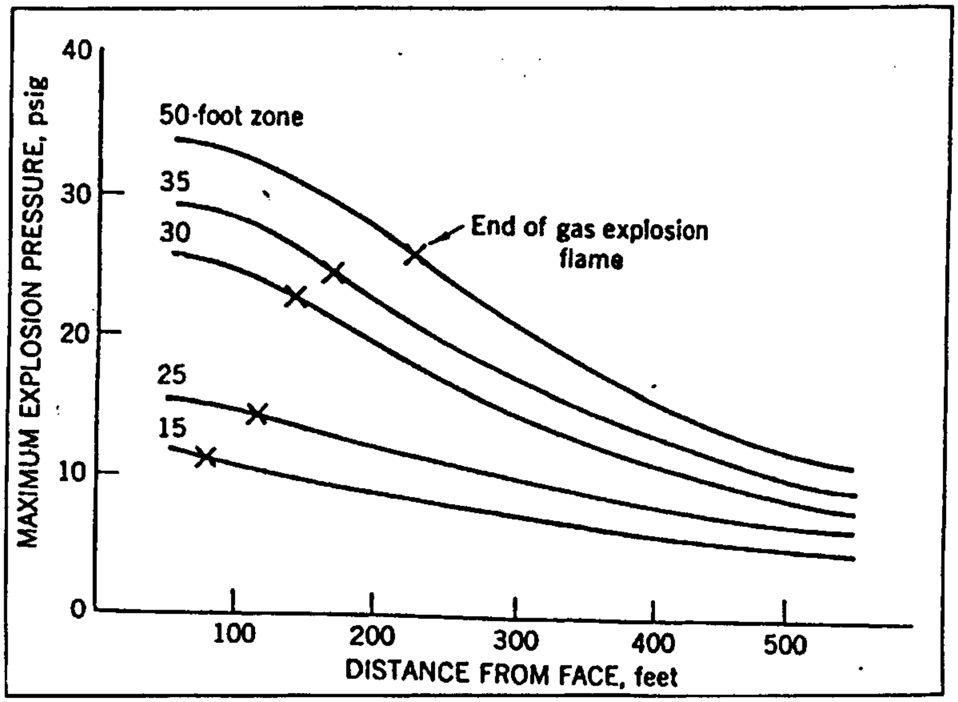

Figure 6 DISTANCE-PRESSURE GRAPH SHOWING THE PRESSURE DECAY OVER DISTANCE

2.3.6 Effects of an explosion in a coal mine

In the underground environment explosions are more complex than those measured in test situations using commercial explosions or a controlled environment. Firstly, although the charge mass is small because of the density of methane, its physical size is usually fairly large and its volume increases significantly during and before the final completion of the explosion. Secondly the explosion is contained within the tunnels, thereby causing a "gunbarrel" effect where the still igniting gases are pushed down the tunnel caused by the effect of the pressure wave being reflected from the walls.

The matter is exacerbated when an coal dust explosion occurs. Firstly the charge mass is now increased due to the coal dust acting as fuel, and, secondly, the explosive is actually caused by the action of the mechanical action of the gases (the coal dust is being physically lifted into the air). Instead of the explosive being depleted during the chemical reaction, it is being supplemented all the time as the explosion progresses, which leads to the phenomena of the peak pressure actually increasing with the distance that the explosion travels (see Figure 4.) This will continue until the fuel or oxygen is depleted, after which the explosion will reduce.

These characteristics of explosions in coal mines could have led Cybulski[10] to note that even though much is known about explosions in coal mines, it is almost impossible to predict their intensity and scope from the fuel and situation geometry.

To give an indication of the severity and extent of explosions, as influenced by the determining factors, Table 2 presents results obtained from major test centres in the world.

Information on the effects of coal mine explosions on humans and structures are usually in a less scientific form and difficult to use. The main reason for this is that when an explosion occurs it is difficult to quantify the strength of the explosion except through its results. As the situation just before the explosion took place also has to be determined, real quantification of a cause and effect relationship has little value. To obtain usable information, a comparison will have to be drawn from commercial or military explosion experience, where significant amounts of research have been done.

Table 2 PRESSURES OBTAINED WITH VARIOUS CONDITIONS IN VARIOUS ESTABLISHMENTS

Test Institution/ (source*)	Test Conditions and Type of Explosion	Static Over-pressure in kPa	Distance from Source
Tremonia[14]	Tests with a coal dust zone 50 % of length containing 80 % inert materials.	25.8 17.1	At source 200 m
	Tests with a coal dust zone 50 % of length containing 80 % inert materials.	28.8 17.2	At source 200 m
Buxton[15]	Coal dust explosions, dust on floor containing 50 % inert materials	49.4	94 m
	Coal dust explosion with dust on floor containing 10 % inert materials.	132.6	94 m
	Coal dust explosion with dust on floor and shelves containing 50 % inert mats.	184.5	94
GP Badenhorst[16]	24 m^3 methane	56	-
	36 m^3 methane	64	-
	40 m^3 methane	72	-
	36 m^3 methane and 20 m coal dust	100	
	36 m^3 methane and 30 m coal dust	150	
	36 m^3 methane and 50 m coal dust	210	

Table 2 (Continued)

Test Institution/ (source*)	Test Conditions and Type of Explosion	Static Over-pressure in kPa	Distance from Source
Lake Lynne[3]	50 m^3 Methane @ 9,5 %	238	15 m
	43 m^3 Methane @ 9,5 %	168	15 m
	35 m^3 Methane @ 10,5 %	112	15 m
Lake Lynne[17]	Weak explosion with coal dust	35	-
	Moderate explosion with coal dust	105	-
	Violent explosion with coal dust	288	-
	Coal dust/methane detonation piling	>700	-
Lake Lynne[19]	Normally expected explosions without excessive build-up of coal dust*2	140	60 m
Barbara[10]	Violent explosion weak initiator-similar to what could happen in coal mine.	57 130 287	200 m 160 m source
	Steady propagation of coal dust in road	200	200 m

*2 Standard test conditions used for testing explosion proof bulkhead constructions.

3 THE EFFECT OF EXPLOSIONS IN THE UNDERGROUND ENVIRONMENT

In assessing the impact of explosions in the underground environment only two aspects will be considered, the effect on humans and structures.

Although this study was involved with the design requirements of refuge bays and refuge bay bulkheads, it is also necessary to determine the effects on human beings. It would be senseless to erect structures underground which could withstand the effects of high intensity explosions when these same explosions would already have caused the death of all those that the structure was intended to protect. In determining the upper range of forces that humans can withstand, a good idea of the practical strength requirement for refuge bay structures is obtained.

3.1 The Effect on Human Beings

Lees[20] identifies the following factors that cause injuries and fatalities in people subjected to the effects of an explosion.

1) Heat radiation or direct burns.
2) Blast effects.
3) Combustion products.

The heat radiation threshold is set[21] at 4,7 kW/m^2 for a period of no more than 30 seconds as burn injuries could occur above these levels of heat and time of exposure.

The biological effects of blast are customarily dived into:

1 Primary - due to variation in local pressure.

Typically the damage caused by blasts is in the form of lesions at or near the interface between tissues of different densities. Air-containing organs are especially affected .

The largest number of injuries or fatalities from blast effects are caused either by the direct blast or the complex secondary waveforms causing accelerations on organ walls in the thoracic region. The lungs are the most susceptible to such damage[22].

2 Secondary - Associated with the impact of debris energized by blast, shock, overpressure, blast winds and gravity.

Secondary missiles can cause a variety of injuries to the body including lacerations, contusions, penetrating wounds and fractures. These injuries depend on the mass, profile velocity and areas of the body, as well as the objects involved.

3 Tertiary- comprising injuries from gross body displacement (translation)

This is mainly due to the body being moved through space and the resultant decelerations encountered when impacting with another body or object.

4 Miscellaneous or indirect examples.

Thermal injuries resulting from fires initiated by hot gases or damage to structures and material.

In the chemical industry gas explosions very similar to methane explosions can occur. The exception being that they are mainly unconfined, so that the main cause of death, when a vapour cloud explodes, is mainly due to the effects of flame inhalation[23].

The extent of the flame radius is similar to the 70 kPa overpressure radius (around the source of the explosion). As the probability of surviving the flame is much lower than the blast effects, the danger threshold is taken to be 70 kPa, rather than the higher values that would be obtained if just the blast and direct heat effects were considered.

The results for blast effects as determined by Williams[42] is presented in the following table.

Table 3 TENTATIVE CRITERIA FOR PRIMARY BLAST EFFECTS

Critical Event[42]	Related Max Pressure psi (kPa)
Felt as a sudden blow	2 (14)
Eardrum failure	5 (35)
Person knocked off feet	6 (42)
Lung damage threshold	15 (105)
Lethality:	
threshold	30-42 (210-294)
50 %	42-57 (294-399)
95-100	50-90 (350-630)

In quoting Glasstone[24] Lees sets out the following relationships between the explosion characteristics and the probability of injury.

Table 4 LETHAL POTENTIAL OF A RELATIVELY FAST EXPLOSION WITH A POSITIVE PHASE OF DURATION 400 ms

Probability of Fatality in %	Peak Overpressure in kPa
1 (Threshold)	245-315
50	315-385
99	385-455

Table 5 RANGE FOR FASTER EXPLOSIONS 1-20 ms POSITIVE PHASE DURATION

Probability of Fatality in %	Peak Overpressure in kPa
1 (Threshold)	100
10	120
50	140
90	175
99	200

Table 6 PROBABILITY FOR THE EARDRUM RUPTURE, THE MAIN NON-LETHAL INJURY FROM DIRECT BLAST EFFECTS

Probability of Eardrum Rupture in %	Peak Overpressure in kPa
1 (Threshold)	16,5
10	19,3
50	43,5
90	84,0

Table 7 PROBABILITIES FOR INJURY FROM A STANDARD MISSILE PROJECTED BY THE BLAST. (10 gm missile with a density of 2.65 gm/cm^3, glass.)

Injury	Peak Overpressure in kPa	Impact Velocity in m/s
Skin laceration:		
Threshold	7-14	15
Serious wound:		
Threshold	14-21	30
50 % Prob	28-35	55
100 % Prob	49-56	90

In assessing the effects on tunnel occupants, Considine[25] puts the lethality range of people being killed by blast damage between 100 kPa (1 % of fatality) and 200 kPa (almost 100 % of fatality).

The longer the period of the pressure the greater the possibility of damage. A pressure of 800 kPa acting for 5 m/s would have the same effect on a human as a pressure of 425 kPa for a period of 20 m/s.

Table 8 TENTATIVE CRITERIA FOR TERTIARY BLAST EFFECTS ON IMPACT AGAINST A HARD FLAT SURFACE[26]

Effect	Impact Velocity m/s
Body	
Mostly safe	3,0
Lethality threshold	6,0
Lethality 50 %	7,8
Lethality near 100 %	9,0
Skull fracture	
Mostly safe	3,0
Threshold	3,9
Lethality 50 %	5,4
Lethality near 100 %	6,9

The above table assumes a travel of approximately 3 m. A longer duration blast, however, can accelerate a body for significantly further distances. Stapczynski[27] calculated that for a typical adult weighting 75 kg a peak pressure of 105 kPa from an explosion can produce an instantaneous acceleration of about 135 m/s^2 or approximately 14 gravities. Whilst in the case of short duration blast the accelerations might only last milliseconds, and, therefore, the ultimate velocity reached by a victim might be very low, longer duration blasts of lower pressure could impart greater movement to a body.

3.2 The Effect on Structures

The majority of work on the effects of explosions on structure was done by the military. In determining the effect, the wave is characterized by the overpressure. The effects on civilian type structures are given below. Very little information with regard to mine structures, except for the testing of seals, could be found.

Table 9 EFFECTS OF PRESSURE ON COMMON STRUCTURES[28]

Pressure kPa (PSI)		Effects
0,14	(0,02)	Loud Noise (137dB)
0,21	(0,03)	Occasional Glass Breakage
0,28	(0,04)	Loud Noise (143 dB)
0,85	(0,15)	Typical Glass failure
7,0	(1,00)	Partial demolition of house
14,0	(2,00)	Partial collapse of walls of house
21,0	(3,00)	Concrete block walls shatter
35,0	(5,00)	Utility poles snap
70,0	(10,0)	Eardrums rupture rarely
85,0	(15,0)	Building totally destroyed
2100	(300)	Fifty percent eardrum rupture
>2100	(>300)	Crater formation Destruction of human body

Structures subjected to the explosions will react differently to the blast of an gaseous explosion than when subjected to effects of High Explosives. The reason being the absence of the stress wave caused by the High Explosive. Elasto-Plastic deformation of the structure will be caused by the "secondary effect" of blast pressure, which has a lower level than that of High Explosions, but is much longer in duration than the stress waves[29].

The effects presented in Table 10 have been noted by researchers[30] studying the effects of military explosives on animals and structures.

Table 10 EFFECTS OF MILITARY EXPLOSION BLAST WAVES

Peak Over Pressure level (kPa)	Effects
20-40	TOL*. Small animals in the open
>55	TOL. 50 -pound animal in the open
190	TOL. Small animals in burrows
320	TOL. Larger animals in burrows
45	Lung damage to small animals in burrows
85	Lung damage to large animals in burrows
20-35	Ear damage to animals in the open

Peak Over Pressure level (kPa)	Effects
35-70	Injury to birds in flight
35-70	Toppling of small leaved trees
20	Damage to tree branches
7	Damage to building walls/roofs
3,5	Skin penetration from broken windows
1,4	Flight hazard to light aircraft
0,20	Window breakage at low incidence
0,20	Impulsive noise limit 140 dB
2	Tinnitus or ringing of ears

* Threshold of lethality (TOL).

4 REFUGE BAYS IN SOUTH AFRICAN COLLIERIES

4.1 Requirements of Refuge Bays

The establishment, maintenance and function of refuge bays are defined in the Minerals Act and Regulations:

"refuge bay shall mean a place in the underground workings which is inaccessible to air containing noxious smoke, fumes or gases and which shall be having regard to the maximum number of persons likely to be present in the area served by the refuge bay-

(i) Equipped with means for the supply of respirable air unless conditions are such that this is not required,

(ii) equipped with a sufficient supply of potable water,

(iii) equipped with first aid equipment,

(iv) of sufficient size to accommodate that number of persons,

(v) equipped with a means of communicating verbally to surface,

(vi) situated where possible in an area free of combustible material."

From the above it can be seen that the main purpose of the refuge bay is to keep workers safe from the effects of poisonous gases and fumes, while the structural requirements of the refuge bay are, thus, that it should be able to stop any ingress of such gases and fumes into bay after an explosion. Although not defined as such in the act it can be assumed that damage to the structure should be contained to the limit that there should not be leaks of sufficient size and number that would allow an inflow of gases into the refuge chamber itself. It, therefore, stands to reason that the construction should also be such that the support systems like water, air and communications should still be available and working after the explosion.

While the refuge bay is not intended to protect workers from the actual explosion, if the refuge bay does not function after the explosion it cannot protect the workers Thus, the question that really needs to be answered is how strong should the design of a refuge bay be in order to ensure the protection of workers in the aftermath of an explosion The stronger the explosion, the higher the strength requirements, but lesser the chance that a worker would be alive to use the bay. Therefore, the practical strength requirements for a refuge bay should not be significantly higher than the pressure at which the probability of workers surviving the explosion and using the bay is minimal The criteria that is used by the majority of countries is the static overpressure generated by the explosive blast

There is, however, another use of the refuge bay that is not influenced by the effect of an explosion, that as gathering place for workers that have been trapped for other reasons. Although the law has not identified this use, the refuge bay should also be seen as a place where the workers can gather in safety until they can be rescued. In this case the whole issue of life sustaining and communication systems becomes more important than the isolation from poisonous gases. Provision for a place of refuge in the case of flooding has not been made for in the law. This might be a shortcoming that needs to be addressed.

4.2 Methods Presently used in Collieries

Information, with regard to refuge bays in collieries, was obtained from the codes of practice as kept in the regional directors offices. These could be considered as the specifications to which mines would erect their refuge bays. Further information was gained from discussions with relevant staff, as well as other parties involved with the rescue of workers in the aftermath of a fire or explosion.

Appendix A presents a table containing a summary description of the construction types, siting, signalling and ventilation requirements for the majority of larger collieries.

Siting of refuge bays

The majority of mines specify the proximity of the refuge bay to be in the order of a kilometre from the working face, with some mines reducing this limit to 700 m and other extending this up to over two kilometres. This would mean that in those circumstance where the furthest permissible distance is used, there is a very low probability that workers would reach safety. Although some of the mines specify times within which the refuge bay should be reached (less than 30 minutes), the distances specified are not compatible with the specified maximum distances, if conditions after an explosion are considered.

Construction of refuge bays

Refuge bays are constructed by two major methods. Firstly a bay or cubby is cut into a pillar forming a blind road. This could be between pillars, or into a pillar itself. The second method is to build two stoppings, or bulkheads, between pillars to form a chamber.

Only one mine specified the thickness of the wall. Apart from this there is no indication of how the mines define the strength requirements.

On the whole, specifications for the finishing of the walls, sealing the bulkhead and safeguarding the pillar walls against spalling, are extensive and deemed to be sufficient.

Supplying of air

The majority of mines provide fresh air to the refuge bay by forcing air down a borehole by means of a fan or blower on surface. It appears that no provision has been made in case of the possibility of an pressure wave moving up the borehole and destroying the fan's operation. The fans are usually not coupled to the boreholes until an incident necessitates it.

There is a discernable trend in the codes of practice that the more detailed the design of the air supply, the longer the distance between the refuge bays.

Although one mine has made provision for routing air between seams, the possibility of multi-seam workings might pose a problem in the supply of air when surface boreholes are being used. This is also borne out by Durant[45].

Design advantages

A large amount of attention has been given to the design of the surface installation to supply air.

In one of the codes, use was made of mesh suspended across the roadway to direct workers to the refuge bay. This is a good concept as such a system would not only have a high probability of withstanding the force of an explosion, but would, in circumstance of low visibility, stop workers from going past the refuge bay.

Identified shortcomings

On the whole no attention is given to ensuring that the placement of signs, lights or directing structures is done in such a manner that they could survive the force of an explosion. These signs, while enabling the worker to become familiar with the placement of the refuge bay under normal conditions, would not assist him in finding the bay, if destroyed or moved by the force of an explosion.

Very little evidence is found in the codes of how the bulkheads, walls or doors are to be designed. It is only pointed out that they should be robust or able to withstand an explosion. Nowhere are actual design requirements laid down, and only in isolated cases are specified thicknesses presented.

It is evident from discussions held with various industry members that keeping fully equipped refuge bays at the required intervals is becoming a problem. The main problem is the access and work on surface in providing the boreholes to supply the fresh air.

Nowhere in the codes of practice is mention made of the overlapping of refuge bays or the procedure of moving refuge bays.

In the majority of cases use is made of methods employing vision to direct or identify the location of the refuge bay. Work done by Van Rensburg[34], as well as post explosion experience, has highlighted the lack of visibility even in the case of fires. This would mean that these signs, although well placed and installed, would have very little effect in getting the worker to the refuge bay.

It is the author's opinion that all the refuge bays detailed in the Codes of Practice studied would be more than adequate to cope with the results, or the aftermath, of an non explosive event that has led to the creation of poisonous fumes and gases. However, when bad visibility and the effects of an explosion have to be coped with, it is doubtful if the specifications will guarantee worker safety.

5 ASPECTS IN THE DESIGN OF REFUGE BAYS

In designing the refuge bay the first consideration must be that the design conform to the requirements of the law.

The second consideration is that it should have a high probability of fulfilling the function it was intended for, in conjunction with self rescuers, as part of the rescue strategy. It should be reachable during the period after an incident occurs and while the worker is dependant on a self rescuer to sustain life. The refuge bay should further be in such a condition that when a worker reaches the bay, after an incident, it should afford the worker the protection it was intended to give.

Another use of the refuge bay is that it can become a place where the workers can be kept safe for longer periods in the events other than fires or explosions. In the case of serious roof falls, for example, it might take longer for the mine to rescue the workers from the underground environment.

Another aspect to consider, regarding refuge bay requirements and the rescue strategy as a whole, is the possibility of second explosions. At present the whole Queensland[31] rescue strategy is being reviewed to take account of the possibility of a second explosion after the first has occurred. This has led to the decision that rescue brigadesmen will only enter the mine after confirmation that a second explosion cannot occur. This implies that rescuers will not always be able to reach the refuge bay in the period that is presently given, extending the time period for help reaching a refuge bay to more than a day. In such an event it would be necessary to have a refuge bay that ensures a longer term air supply. However the possibility of a second explosion is regarded as highly unlikely in South Africa[32] and longer term usage of a refuge bay would be more dependant on accessibility factors than the unwillingness of management or the DME to allow the rescue brigadesmen underground. In any case the use of a large-diameter surface borehole would be considered under these circumstances.

McCracken[35] quotes the possibility of explosions being caused by the products of fires in the underground environment. This is usually prevented by the ventilation sweeping these gaseous products beyond the fire and the other products of the fire creating a barrier between the fire and the explosive mixtures. In the event of the ventilation stopping, or surges in airflow being experienced, the probability of an explosion could increase significantly. This might affect the presently held attitude of sending brigades men into a coal mine after an initial explosion or underground fire.

5.1 Placement of Refuge Bays

During an exercise to determine the distances that could be travelled by workers in the aftermath of an explosion, Van Rensburg, JP *et al*[34] found that due to problems with low/zero visibility the refuge bay should be placed within 500 m from the work areas. The exact distance requirements will, however, be influenced by the method used to assist workers to find the refuge bay.

It was recommended that less formal bays be considered, thereby allowing the escape distances to be shortened. These bays should, however, be accurately pinpointed on mine plans so that the surviving miners can be reached by boreholes.

Travelling roads should be regarded as the preferred escape routes and guidance should be provided right up to the door of the refuge bay, with unused entrances barricaded or guidance system provided to prevent accidental entry during escape conditions.

These local findings are well supported by the distance specifications as determined by Maser *et al*[8] who gives the following figures for placing the refuge bay.

> For a sixty minute movement period, the distance that can be travelled by workers has been identified to be:
>
> - below 0,76 m height the distance to shelter should be no more than 457 m
> - below 1,07 m height the distance to shelter should be no more than 760 m
> - below 1,52 m height the distance to shelter should be no more than 915 m
> - above 1,52 m height the distance to shelter should be no more than 1 220 m

Since initially following an incident there is a period of time required to think and orientate oneself and these figures have been based on a sixty minute self-rescuer, the distances can be more than halved to obtain the required distances for local self-rescuers, with a duration of thirty minutes.

5.2 Discussion of the Strength Requirements

The majority of work throughout the world into the strength characteristics of bulkheads has been in terms of seals. Although the forces that will ultimately impact on a seal might be different to that of a refuge bay bulkhead, and the severity might be higher, the method in which these seals were tested provides information of great value.

In both Europe and the UK, bulkheads are required to withstand pressures of up to 500 kPa, which is seen to be the upper limit of static pressure reached by an explosion of moderate strength[8,10].

The negative pressure that a wall would experience is determined to be in the order of less than 7 kPa. However work done by Westinghouse[8], and Nagy[17] indicates that provision should be made for the wall to withstand a negative static pressure of 35 kPa.

To destroy a structure it is necessary for the pressure not only to reach or exceed that which would be necessary to bring about static failure, but also for it to do it for long enough to carry the element forward sufficiently to obtain the critical deformation[40]. With a gaseous explosion the time of the pressure wave is usually longer than with high explosives and, therefore, this critical displacement is usually achieved if the pressure is sufficient to enable failure.

Structures should thus be built strong enough to withstand the static loading or be physically of such size that displacement of the elements during the overpressure period does not cause critical failure of the structure. Efforts directed at restricting movement of the elements will also assist in maintaining the integrity of the structure.

Work to determine the strengths of buildings to withstand the effects of internal gas explosions[41], found that because walls have a natural frequency less than that of the rapidly changing pressure of the wave front, these changes would be almost completely absorbed by the mass inertia of the wall. To refer back to the conventional static basis, a formula was derived to give a uniform static loading on the wall.

Explosion load $P = 3 + P_v \ kN/m^2$
Where P_v is the recorded static pressure of the explosion (at the wall).

In the tests done at the Lake Lynne facility of the USBM in the USA evaluating various types of seals, Weiss, Greninger and others[4,5,6] specify the pressure that seals have to withstand, both for purposes of formulating revised regulations[7] and for the test purposes, as 20 pound per square inch (140 kPa). In testing these seals they were so constructed that they were placed in a cross-cut which means that the pressure pulse was obtained side-on to the main pressure wave. This meant that the seal was not subjected to the dynamic force of the explosion, but only to a standardized rise in static pressure which was presented head on to the seal. The pressure wave was obtained through the ignition of a 14 m long, 2 m high and 5,8 m wide volume of 10 % methane air mixture. To obtain increased pressures (25, 30 and + 35 psi or 180, 215 and +250 kPa), use was made of coal dust placed on shelves close to the roof.

This would lead to the conclusion that in the case of a methane explosion in a heading, without coal dust taking part, it would be highly improbable for pressures a distance away from the heading to exceed 140 kPa (20 psi).

Although local pressure increases can be expected due to reflection of waves off solid objects, there could also be a significant reduction due to the attenuation of the waves going around corners or through intersections.

It should be noted that to enable testing at even higher pressures the explosion wave had to be generated through the use of blasting powder.

In trying to determine what pressures should be accounted for when designing bulkheads, Maser[8], in determining the strength characteristics for reusable bulkheads, found that the only two sources for experimental data are the US Bureau of Mines and the European Community for Coal and Steel.

In quantifying the resistance of bulkheads to explosion forces Mitchell[42] notes that it is impossible to foretell what forces could be expected in the case of coal dust explosions. He notes that work done in the USBM's experimental mine have produced pressures ranging from 1 to 127 psig, and, in some cases, pressure piling caused even higher, but unrecordable pressures. In considering the pressures that bulkheads are subjected to, it must also be assumed that the area is stonedusted according to the requirements of the law. This would lead to a reduction of the wave, through attenuation, when the wave travels through the inertised area. This is what could have led him to conclude that at distances of greater than 200 feet (60 m) from the origin, and where the coal dust accumulations are not excessive and the incombustible contents within the legal requirements, the pressure will very seldom exceed 20 psig (140 kPa).

Other investigators[8] have found that for a side-on exposure a value of 20 psi (140 kPa) overpressure should be used, but for a head-on close or direct explosion, this value could be insufficient as pressure of up to 30 psi (210 kPa) have been measured.

The duration of the pulse of the wave is in the order of seconds or fractions of a second. As this duration is much longer than the response time of the structure, the structure will respond to the pressure pulse as if it were a step loading.

It is then further stated that research in the United States and in other countries indicate that bulkheads designed to withstand a given static load will have a considerable margin of safety should it be subjected to a greater dynamic load, for example, in a test conducted in the experimental mine a bulkhead designed to cater for a static load of 14 psig (100 kPa) withstood 27 explosions developing from 5 up to 50 psig (3,5 to 35 kPa).

Work done recently in Australia[35] to determine seal strength also confirm these previous findings.

Table 11 STRENGTH REQUIREMENTS FOR SEAL IN OTHER COUNTRIES AS SUMMARIZED BY MCCRACKEN[35]

Country	To Withstand a Overpressure of:
Germany	525 kPa
United Kingdom	350 kPa
United States	140 kPa (60 m stonedust inbye)
Australia (proposed)	
Normal conditions	140 kPa (100 m stonedust inbye)
Extreme conditions*	345 kPa[36]

* These extreme conditions are specified to be "When persons are to remain underground whilst an explosive atmosphere exists in a sealed area and the possibility of spontaneous combustion, incendive spark or some other ignition source could exist". This means that there is a high potential for a contained explosion to occur behind the seal.

Latterday work in Australia into the design of normal seals favour the standard adopted by the United States, but have added a precaution of heavy stonedusting for at least 100 m inbye from the seal. The purpose of this is to ensure that there are sufficient suppressants to prevent any coal dust explosion and to dampen the methane explosion.

5.3 Proposed Strength Requirements

In proposing a strength requirement for a refuge bay bulkhead the following factors were assumed or taken into account.

1) The refuge bay would not be built closer than 100 m to the face.

2) As the most severe pressures are experienced at the face, any other point of ignition would lead to lower or equivalent pressures at the refuge bay.

3) In the light of legislation and industry awareness the probability of a coal dust explosion is now very low. Provision is made for the more likely occurrence of a methane explosion.

4) There is little purpose in designing a refuge bay if the explosion has been so violent that there is an insignificant chance of survivors. In bord and pillar workings a gas explosion is virtually uncontained. Since the maximum pressure that can be reached in a totally uncontained gas explosion is 112 kPa, a good estimate of the maximum pressure in bord and pillar workings would be 140 kPa.

5) At 140 kPa overpressure the effects on people working in the section would be:

   (i) for very fast explosions about a 50 % fatality rate, while for slower explosions this could fall to less than 1 %
   (ii) almost certain probability of eardrum rupture
   (iii) some workers would have suffered lung damage
   (iv) probability that some workers would have been struck by missiles.

   However, there is a strong probability that up to 50 % of the workforce would still be alive following the explosion.

6) At overpressures of 140 kPa most normal building walls and stoppings would have been destroyed and concrete walls or brick walls less than 300 mm in thickness would be seriously damaged.

It is therefore proposed that the strength requirements that a refuge bay bulkhead should withstand is an overpressure of 140 kPa (1 Bar) and a pulse period of 0,25 ms. By using these specifications to design the refuge bay, the following criteria or implications can be accepted.

- The requirements will be equivalent to requirements for structures in the USA and Australia.

- Designs for seals and bulkheads produced by the USBM can be used with safety.

- A deflagration type of methane explosion will be adequately catered for.

- The bulkhead would be capable of withstanding pressure from a methane explosion in an open volume.

- The bulkhead would not cope with a contained methane explosion, methane detonation, or a violent coal dust explosion.

- It would cope with a moderate explosion, with some participation from coal dust.

Thickness of the bulkhead

Initial work (1930) done by the USBM[8] using 350 kPa pressures (obtained through the use blasting powder) indicated the following relationship between thickness and width, if the bulkhead is to survive.

Thickness(T) >= Width/10

Rib Recess(R) >=Width/10

For soft coals this relationship was changed to:

Thickness(T) >= Width/8

Rib Recess(R) >=Width/5

In all cases the bulkhead thickness had to exceed 300 mm.

In later work (1970-1973)[37] tests were also conducted to an upper pressure limit of 350 kPa from which the following specifications were derived. These are presented in Table 12.

Table 12 USBM RECOMMENDED STANDARDS FOR ACCEPTABLE BULKHEADS FOR NORMAL MINING SITUATIONS

Type	Minimum Thickness
Concrete	t/4
Concrete reinforced	t/10
Concrete block	400 mm
Fly ash	t/4
Gypsum	t/4
Rock, grouted	W+H/2
Rock, packed	2t
Sands bags	WH/3

Where t = W or H, whichever is the greatest.
W = Average width of the passageway, and
H = Average height of roadway, plus the depth of recess for concrete block and reinforced -concrete bulkheads.

In the above table the following principles have been used.

- Sandbags are usually jute bags filled with loose sand and stacked in the roadway.

- Concrete, both reinforced and plain, consisting of sand, cement and gravel, with a compressive strength of approximately 21 MPa and tensile strength of 2,45 MPa.
- Concrete blocks are prefabricated blocks that have been used with cement mortar to build either a single or triple layer (course) wall.
- Fly-ash and gypsum are mixtures with flexural strength varying from 0,7 to 4,2 MPa.

Holding[39] in setting out means to design mine seals to withstand the effects of coal dust explosions uses the following formula to determine the thickness of the seal:

$$\text{Thickness} = \frac{P_o \times A_m}{2(w + h) \times f_s}$$

Where P_o = maximum explosion pressure in MPa
A_m = cross sectional area of stopping in m^2
w = width of stopping
h = height of stopping
f_s = shear strength of concrete or coal, whichever is the lesser.
f_s for concrete is taken to be 15 to 25 MPa
f_s for coal is taken to be 5 MPa

It is calculated that to withstand a coal dust explosion with a pressure of 700 kPa and using a safety factor of 3, the resultant seal thickness in a roadway with dimensions 6 m x 3 m would be a 9,6 m long plug of concrete. Such constructions would by their very nature be impractical for a refuge bay bulkhead.

The formula can, however, be transposed to give the relationship between the thickness of the seal and the area of the seal as follows:

$$\text{Thickness} = A_m \left(\frac{P_o}{2(w + h) \times f_s} \right)$$

5.4 Design Aspects to Increase the Strength of Refuge Bay Bulkheads

As it has been noted that there are high local reflected pressures at short distances down the cross-cut, it would be desirable to build a bulkhead flush against the crosscut to prevent these reflections from occurring.

In studying the response of structures subjected to severe dynamic loads it was found that materials with fibres imbedded reacted much better to withstanding the effects of pressure pulses.

Based on work done to develop explosion proof structures[39] the following principles have been identified to be used in increasing the strength of bulkhead walls.

Energy Absorption

When using this principle the wall or bulkhead absorbs the shock/overpressure or temperature, but has enough strength to maintain its integrity and stability, as well as the ability to seal out the atmosphere. This can be achieved through various methods.

Energy Dissipation

To dissipate the energy a sacrificial wall element may be employed to absorb energy and, in so doing, dissipate the energy before reaching the refuge-bay wall. Loose rock or debris may be placed in a gabion type structure in front of the wall to dissipate energy.

Energy Deflection

Provide a sacrificial chamber or structure to channel the shockwave away from the refuge-bay structure.

The walls can be made more ductile by affixing reinforcing bars on the inside and spraycoating them to the walls with a joining and covering medium[44].

There are distinct advantages in increasing the tensile strength of concrete, either cast or sprayed, by the addition of fibres. The fibres, which can consist of materials ranging from polyethylene, Kevlar, glass, carbon, etc substantially increases the tensile strength of the material without the use of reinforcing steel[43]. Research currently being conducted at the Lake Lynne facility by the Australian company, Tecrete, makes use of these principles.

5.5 Practical Considerations with regard to the Establishment of Refuge Bays

5.5.1 Practical considerations in the placement of refuge bays

In deciding the placement of the refuge bay the first criteria is that it should be within reach of the workers it serves. From local and overseas work this distance lies in the order of less than six hundred metres.

To comply with these requirements it would be necessary for the mine to erect a refuge bay at time intervals ranging between 36 shifts for a very low seam (0,75 m) to about 185 shifts for a high seam (5,0 m). The time to erect such a refuge bay would also be commensurate with the height of the seam being mined due to the increased thickness requirements of the bulkheads for higher seams. (Figure 7 represents a schematic graph indicating times between the completion of a refuge bay for different seam heights.)

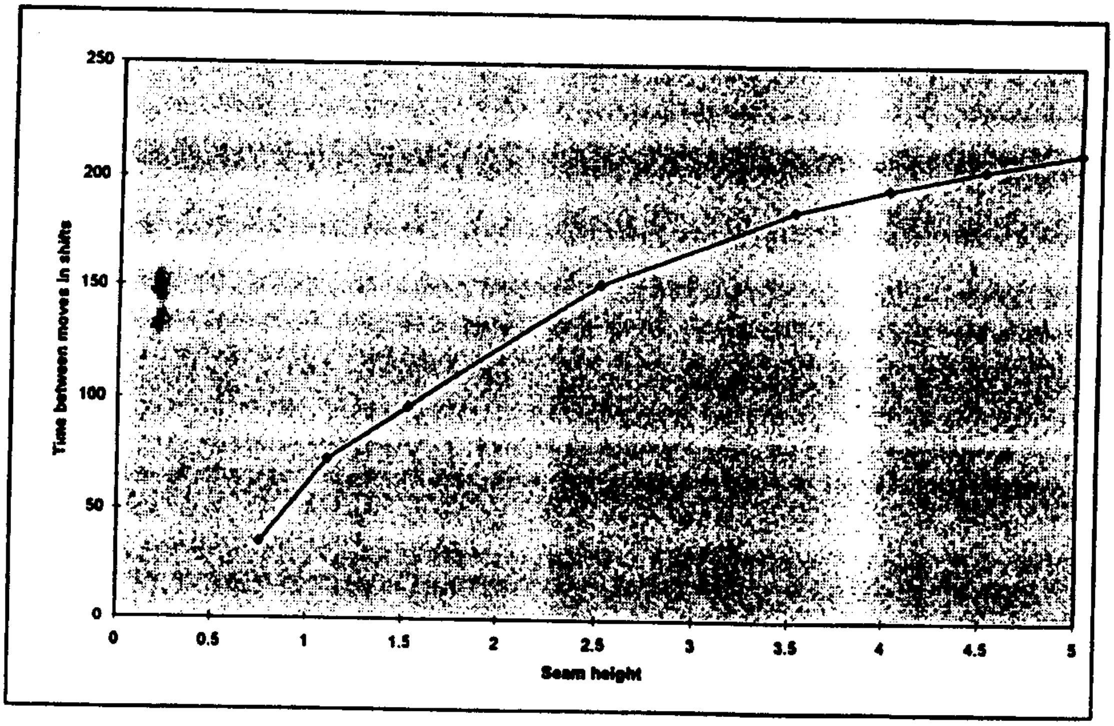

Figure 7 TIMES BETWEEN ERECTION OF REFUGE BAYS, MAINTAINING THE REQUIRED DISTANCE, FOR DIFFERING SEAM HEIGHTS

To comply with the above, and considering the number of sections in collieries, it can safely be assumed that mines would require a full-time team busy building bays.

Ventilation requirements further exacerbate the matter. A borehole from the surface to supply air over the longer term to trapped workers means that for every advance of 600 m a hole will have to be drilled from surface, as well moving the surface installation to the new position. If the property belongs to the mine the effects of such work on surface might not cause problems. However, if the surface belongs to a private owner problems could occur if these types of activity are conducted.

It should also be remembered that when these holes have completed their function they will need to be sealed off.

All in all it would seem that compliance with the distance requirement would be onerous and costly for the mines.

The solution, as indicated by these practical considerations, is therefore an alternative arrangement.

5.5.2 Practical consideration with regard to strength and design of refuge bays

If the shelter is chosen to be close to the working place then economics will dictate that it be of a lightweight, portable and reusable nature. If these shelters are to be a permanent structure in or around the main haulage routes, then it might be more economical to use monolithoic structures[8].

The building of the bulkhead at speed, as in the case of building seals to confine a fire, need not be considered.

Use must be made of the coal surroundings, as it would have a comparable or higher strength than concrete and exists in bulk. The coal need also not be sealed.

Where cubbies or chambers are cut into coal the effect of a pressure differential over walls between mine passage ways are also excluded.

Durant[45] notes the following aspects with regard to supply of air to refuge bays.

- Accepted practice for ventilation is by boreholes from surface or by piped compressed air from surface.
- Found that this process is difficult in deeper lying seams such as the mountainous areas of Natal.
- Proposes the use of compressed air cylinders. Provision is made for a maximum of 9 hours.

Work done by Kielblock *et al*[46] has shown that without ventilation the CO levels in a refuge bay, due to contamination from door openings and leaking to the inside of the bay, could reach the TLV within 8,5 hours. This is when there is no supply of air to the bay and the outside level is in the order of 1,5 % carbon monoxide. In the event of this level dropping to 0,25 %, the time required to reach the TLV is extended to 72 hours. A conservative estimate of life support in a refuge bay without air is taken to be in the order of 5-8 hours. Compare this to the Gloria fire experience where no explosive forces were present and the time required to reach the miners with a rescue drill was about 21 hours and to get them out about 46 hours[47].

This means that for bays where workers are to stay for longer periods there must be a method to flush out the air or create a positive pressure inside the bay. The use of oxygen might not be sufficient to ensure that the level of CO and CO_2 caused by exhaled breath does not reach dangerous limits.

This also emphasizes the importance of sealing the door to ensure that no poisonous gases enter the bay during, or shortly after the incident, or when there are workers inside after the incident.

6 CONCLUSIONS

6.1 Characteristics of Explosions

From the literature and worldwide experience it is evident that there is not such a thing as a typical explosion as the pressure rise, duration and other characteristics can be influenced by many factors.

Using the standards as adopted by the United States as well as Australia, i.e. an explosion with an overpressure of 140 kPa, the strength requirements of the refuge bay bulkhead can be specified and these would cater for a very large proportion of the possible incidences.

This level of strength is deemed to be sufficient to cater for explosions that could still occur even if the preventative steps to prevent coal dust explosions are fully operational. To ensure that there is no risk of a coal dust explosion effects close to the bays, stonedust should be kept to the 80 % level of inert materials for a perimeter of at least two pillars around the bulkhead (based on US and Australian criteria.).

6.2 Design Criteria for Bulkheads

There are no universal methods that can be readily applied to the design of bulkheads without testing them in a facility where the explosive forces can be simulated.

Use of the standards as proposed for the USA, and as contained in the appendices of this report, will, however, form a good basis on which mines and structural designers can produce designs specific to their local conditions of seam height, roadway widths, etc.

Acceptance of this overpressure standard will allow the use of overseas technology to design bulkheads without the industry incurring the costs of testing them.

It is doubtful if mines will be able to construct refuge bays much closer than a hundred metres from the face which means that when the explosion is only an ignition of methane the pressure levels should not exceed 140 kPa.

Designs for local conditions should be directed at achieving the required strength while using readily available and cost effective building materials and techniques.

6.3 Present Practice with Regard to the Construction of Refuge Bays

The present practice of constructing refuge bays conform to the law. It is however evident that the practice does not yet encompass the practicalities of reaching the refuge bays in the available time. On the whole the distance between the working face and the refuge bay would not be travelled in the event of bad visibility or disorientation of the workers.

On the whole the infrastructure of the bays, as presented in the codes of practice is more than adequate.

The use of current methods to supply air by replacing the oxygen in the air without causing a positive pressure or diluting the CO and CO_2 in the chamber might lead to dangerous poisonous gas levels in the bay, as air permeates in.

6.4 Width to Height Ratios

There is no universal safe ratio between the width and height of bulkheads as this ratio is dependant on the basic type of construction and the materials used. The ratios as presented have been tested and found to be relevant for the particular design application. New designs will, however, have to be determined either empirically by testing or by comprehensive analysis.

6.5 General

The issue of keeping the refuge bay within reachable distance from the face is seen to be one of the most important aspects identified in this study although it was not part of the original scope. Attention will have to be given to address this problem.

7 RECOMMENDATIONS

The following recommendations have been indicated as a result of this study.

A standard should be decided on for the design of refuge bay bulkheads. It is recommended that an overpressure of 140 kPa be used as the most appropriate level of explosion to be protected against.

A method of testing bulkheads for strength and leakage characteristics will have to be established.

In testing these bulkheads use must be made of the same type of construction methods which is used underground. The way that a bulkhead is constructed in practice will have a greater effect on its strength than the way that the bulkhead is designed. It would be of benefit if the actual staff that is going to build these bulkhead do the construction in the test facility.

Such a facility would allow new, innovative and locally appropriate designs to be tested. It further foreseen that the establishment of such a facility could be relatively cheap as the only parameters that would have to simulated would be the explosive pulse in terms of overpressure and time. It is quite conceivable that such a facility could be powered by commercial types of explosion that have been customized to give the right results rather than use methane and coal dust to obtained the explosive forces.

Methods should be found that will enable the ease of building and equipping the refuge bay rather than focus on the cost of labour and materials. If the refuge bay could be built at a significantly faster rate it could be kept close to the working face where it would have the greatest lifesaving potential.

To address the problem of maintaining a close distance to the workers the use of intermediate havens and alternative rescue strategies will have to be looked at. This would entail work into the following aspects.

(i) The concept of intermediate havens closer to the section and refuge bays at more convenient and cost effective locations should be investigated.

(ii) The specifications for the signs and the devices that lead workers to the refuge bay must such that they must have a high probability of surviving the effects of an explosion.

(iii) Considerations should be given to the design of refuge bays that are easy to build and can withstand the effects of an explosion by maintaining the sealing against the ingress of toxic gases rather staying structurally sound.

(iv) The design of methods that will minimize the ingress of poisonous gases during the explosive overpressure.

(v) The use of methods to supply air in a safe haven as well as methods to keep equipment safe from explosion blast in such a safe haven.

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APPENDIX A

SUMMARY OF REFUGE BAY SPECIFICATIONS FOR A GROUP OF SELECTED COLLIERIES

The summary specifications as contained in the tables have been obtained from the codes of practice for refuge bays as obtained from the relevant area directors' offices of the Department of Minerals and Energy.

Colliery	Type of construction	Site	Refuge Bay Indicators	Signaling devices	Borehole to Surface	Ventilation Arrangements
Colliery 1	Cut into solid coal with a single entry which shall be away from the most probable direction of an explosion and bricked off with two 0.4 m thick stopings equipped with steel man doors	Spaced at intervals not exceeding 1350 m from the downcast shaft or working section. Not positioned between an intake airway and return airway	12 Volt light illuminating a refuge bay sign equipped with a 12 Volt orange flashing beacon displayed at the entrance to refuge bay	12 Volt siren at the entrance and on the fresh air side of the stoping isolating the return airway from the intake and positioned in the traveling route to the bay	250 mm diameter. Provided with grouted 200 mm casing pipe protruding approximately 1 m above ground level	12 Volt fan coupled to surface borehole
			If the refuge bay is situated in a return airway the stoping isolating the return airway from the intake and situated in the route to the refuge bay is to equipped with an airlock and a 12 Volt indicator light in the fresh air side	Sirens to be able to be activated from inside the bay	2 m2 x 100 mm thick concrete plinth cast around borehole on surface and protected by 2m x 2m x 2m high lockable expanded metal enclosure. Site of borehole acessible to equipment and vehicles	Astron KB 55 petrol powered air blower available for each refuge bay. To be kept in the mines Rescue Room
			220 Volt Refuge bay signs installed at the turn-off points to the refuge bay. Number of R/B to be painted inside and outside of bay		Number of refuge bay to be painted on borehole enclosure	Emergency 12 Volt fans that can be operated from a 12 Volt car battery available in the Proto Room
Colliery 2 Mine 1		Distance to the refuge bay from the working section not to exceed 1325 m				
Colliery 2 Mine 2 Seam 2		Distance to the refuge bay from the working section not to exceed between 700 and 800 m				
Colliery 2 Mine 2 Seam 4		Distance to the refuge bay from the working section not to exceed between 750 and 1800 m				
Colliery 2 Mine 2 Seam 5		Distance to the refuge bay from the working section not to exceed between 800 and 2750 m				
Colliery 2 Mine 2 Seam 2		Distance to the refuge bay from the working section or main downcast shaft not to exceed 300 and 1280				
Colliery 2 Mine 3 Seam 4		Distance to the refuge bay from the working section between 530 and 730 m				
Colliery 3	Brick walls between two pillars. No flammable materials to be used	In the intake airway next to the main traveling route at a distance not greater than 1500 apart and next to a return airway where the pressure differential across the walls will cause leakage to the return airway	Clearly visible reflective or illuminated "Refuge bay" symbolic displayed at the entrance. Conveyor belt strip curtain leading from the furthest side of the conveyor adjacent to the refuge bay up to the refuge bay entrance	Flashing light and siren situated outside the Refuge bay interlinked with the borehole fan	Inside diameter not less than 150 mm	Borehole equipped with a battery driven suction fan in the refuge chamber. Fan to start automatically when a trip switch mounted on the outside of the bay is activated by a percussion wave
			Flashing light and siren situated outside refuge bay interlinked with borehole fan			Portable blower fan on surface able to be coupled to the top of the borehole to be used as backup. Adjustable regulator to be fitted to allow a positive flow of air from the R/C into the U/G atmosphere

Colliery	Type of construction	Site	Refuge Bay Indicators	Signaling devices	Borehole to Surface	Ventilation Arrangements
Colliery 4	Fire resistant materials Double walls plastered on both side to provide effective sealing Must be capable of being sealed off or equipped with an alternative effective means to prevent the entry of noxious gases	Distance from any working section not to exceed 1200 m	International symbolic sign together with the number or name of the refuge bay in reflective lettering to be displayed at the entry	Automatic alarm connected to the emergency power source to be activated automatically during power failures	Cased, 208 mm diameter to surface Casing to be earthed on surface and underground Top borehole casing to be fitted with cap or permanent fitting for blower	Blower unit with all accessories (12 V back up power)
			Bright flashing warning light mounted outbye of the bay in the traveling road and one additional light in the belt road with battery back up provision Conveyor road to be used as the escape way to a refuge bay	Mechanical siren positioned on the outbye and operated from the inside as a back up system	Top of cap to be built of expanded metal to allow air to be drawn in by underground blower when activated Top of borehole to be clearly demarcated	
			A low wall 1 5 m high is built next to the conveyor structure at the rescue bay position as a means of guiding evacuees to the bay		Area of 10 x 10 m to be securely fenced around the hole with one main gate Borehole to be earthed with an earthmat and equipped with a lighting arrestor	
Colliery 5	Cut into solid coal with a single entry Brick walls to be hitched in to the rib sides and have an impervious or concrete floor	On a main intake traveling way at intervals not exceeding 1250 metres at every main or secondary development and where the distance from the working face to the nearest point accessible on surface exceeds 1250 metres	Reflective sign at entrance to the bay Orange flashing beacon to be installed outside the bay	Flahing beacon and siren installed outside the bay	Inside diameter 200 mm Top and bottom of borehole casing to be earthed and any cables in the borehole to be bonded to earth at the top and bottom	Battery drive suction fan in the refuge bay to start up automatically when a concussion activates a trip switch mounted on the outside of the bay This switch will also activate the siren and the flashing beacon outside the bay
			Number of refuge bay to be displayed inside and outside			Portable fans on surface to be coupled to the top of the borehole when required
Colliery 6	Mock evacuation drill only					
Colliery 7	Inside of chamber to be sealed with an effective sealant	At a appropriate distance from working places with consideration given to traveling conditions, capacity of Rescue Pac, ease of access on surface intake ventilation system	Directional arrows along all blue lines along conveyor structure Conveyor belt strips hanging from the roof from the entrance of the refuge chamber across all the intake roadways Audio/visual alarm system at the entrance of the Refuge chamber	audio/visual alarm system able to be activated from the inside of the chamber	300-350 mm borehole with 250-300 mm casing T exit in a cabin constructed with hollow blocks or expanded metal with a corrugated iron roof	From surface through the borehole by means of a 12 volt battery operated dual fan system with a duty of 0 3m3/s at 300 pa One fan on surface and the other underground on a ring feed system and can be operated from u/g or surface
Colliery 8	Cut into a pillar brickwalls with tight steel doors	Between 500 and 700 metres from the section	R/C outside wall painted with 100 mm red/yellow chevron stripes Number and/name of refuge bay to be painted on the outside Symbolic signs indicating the direction to the refuge bay to be installed every 200 metres along traveling routes	One alarm outside the chamber capable of being operated manually from inside the chamber One audible alarm with connecting jack able to be connected to surface supply	150 mm, cased and earthed Semicircle radius of 30 metres to be demarcated and prepared for heavy vehicles Borehole casing to be earthed to a earth mat and to be fitted with a lockable cap and permanent blower fitting 100 mm in diameter	Portable blowers on surface
			Conveyor belt strips in all roadways in the split in which the Refuge Chamber is situated		All roads to surface sites to be passable by 50 ton truck in any weather conditions	

Colliery	Type of construction	Site	Refuge Bay Indicators	Signaling devices	Borehole to Surface	Ventilation Arrangements
Colliery 9	Robust construction and able to withstand the effect on an explosion		Reflective type "Refuge Bay" symbolic sign at entrance to refuge bay Escape routes to be marked with recognized symbolic signs or other physical means	Audible signaling device outside the bay	Provided, taking into account access requirements for equipment and vehicles to the borehole site	Reliable source of respirable air so as to ensure proper flushing and create a positive pressure
Colliery 10	Mined out of a solid pillar If this is impossible the walls will be protected against an explosion by stacking rubble at least 3 0 m high against the walls	Not more than 1000 metres from the production section along or as close as possible to the main traveling route	Conspicuous flashing light and effective siren outside the R/B powered from the battery backup Refuge bay symbolic sign at entrance and in vicinity of travelling routes and walkways	Conspicuous flashing light and siren outside the refuge bay	Cased borehole at least 150 mm diameter Proper protection to surface areas about boreholes as well as proper identification to be provided	12 Volt battery fan connected to the borehole in case of emergency, and able to be switched on from the panel in the refuge bay Able to handle at least 0 1 m3/s of air
Colliery 11	Fire resistent robust materials	Not further than 1200 m fom any point of the mine	Yellow continuous flashing lights in travelling road Red flashing lights and alarm linked to the back up poer supply, installed in the travelling way	R/B to be suitable and clearly numbered outside, inside and on surface Yellow continuous flashing lights at tunnel doors at each R/B	250 mm diameter with 200 mm steel casing To be earthed and enclosed in an expanded metal cage with lockable gates Flag with number of R/B installed at any top corner of metal cage	12 Volt DC emergency fan Non return flap at bottom of steel casing to prevent fan recirculating Amber flashing light and siren on top of metal cage activated from U/G whenever the U/G flashing light and audible device are activated
					Amber flashing light and siren on top of metal cage, activated from U/G whenever the U/G flashing light and audible device are activated Petrol blowers and accessories available on surface to replace the 12 V DC fan	
					All roads to surface sites to be acessible by car even in wet weather They shall be clearly demarcated with symbolic signs and the number of the refuge bay	
Colliery 12	Double flat brick walls between two pillars Rib sides and roof to be teated with gunite after bolting and wiremesh All walls pinned and gunited or plastered on both sides	Within 20 minutes walking distance or approximately 1000 metres of any working place	Reflexive markers and guide aids in all acess routes and refuge bays Flashing amber light outside the refuge bay and working at all times	Mechanical siren situated outbye and operated from the inside	100 mm diameter	Reliable supply of breathable air to be supplied from surface by utilising a high pressure blower
Colliery 13	Robust construction hitched into the pillar To be gunited inside on both ribsides and stoppings to ensure it is properly sealed	Not more then 1000 metres from the working faces underground	Numbered inside and outside Symbolic sign displayed at both entrances	Where possible audible alarm activated from the inside of Refuge bay, and a conspicuous light outside R/B entrances	If possible	If there is no borehole Oxygen bottle with Regulators and spanner
Colliery 14	Ribsides and roof to be treated with gunite after bolting and wire mesh All walls to be pinned and gunited or plastered on both sides All walls to be constructed of double flat breeze blocks	Within 20 minutes walking distance or approximately 1000 metres of any working place Where this not possible safe places to be intalled within 1500 metres from faces	All refuge bays and acess routes to be demarcated with reflective markers	Audible alarm situated outbye and able to be activated from the inside	No	Two axial flow fans, one on dundas seam, one on Gus seam, with independent power supply from respective seam level In case od mishap in Dundas area, Gus fan to be started Each fan to have separated stop/start stations inside the refuge bay

Colliery	Type of construction	Site	Refuge Bay indicators	Signaling devices	Borehole to Surface	Ventilation Arrangements
	Walls to be built at least 5m from pillar if not located in a dummy pillar (preferred)	Not to be positioned next to a return airway. Area well supported and safe and not liable to be flooded. Area to offer easy acess by means of inter-seam inclines. Sited where possible as a dummy roadway with solid ribside forming back of chamber				Reliable supply of breathable air to be supplied via an incline inter seam escape way suitably equipped with a ladderway
Colliery 15	Bay to be cut into the barrier pillar on the intake air side of the section - opposite a pillar whenever possible. On a double header section the bay is to be cut into a pillar adjacent to the tractor road	Refuge bays to be constructed once the section has advanced 200 m and thereafter at 300 m intervals or where practical. Every 5th built in line with main development will become a permanent refuge bay		M O S E S repeater direction alarm system	yes, 152 mm diameter	Oxygen candles according to the capacity of the refuge bay

APPENDIX B

RELATIONSHIP BETWEEN DYNAMIC OVERPRESSURE AND WIND SPEED

In describing the effects of explosions on human being the following table has been used to determine the speed of the winds and the dynamic pressure causing them.

Relationship between dynamic pressure and the wind velocities calculated at sea level (Cook, M.A. Shock Waves in Gaseous and Condensed Media. The Science of High Explosives. New York, Reinhold Publishing Corp. 1955. pp 322-352.)

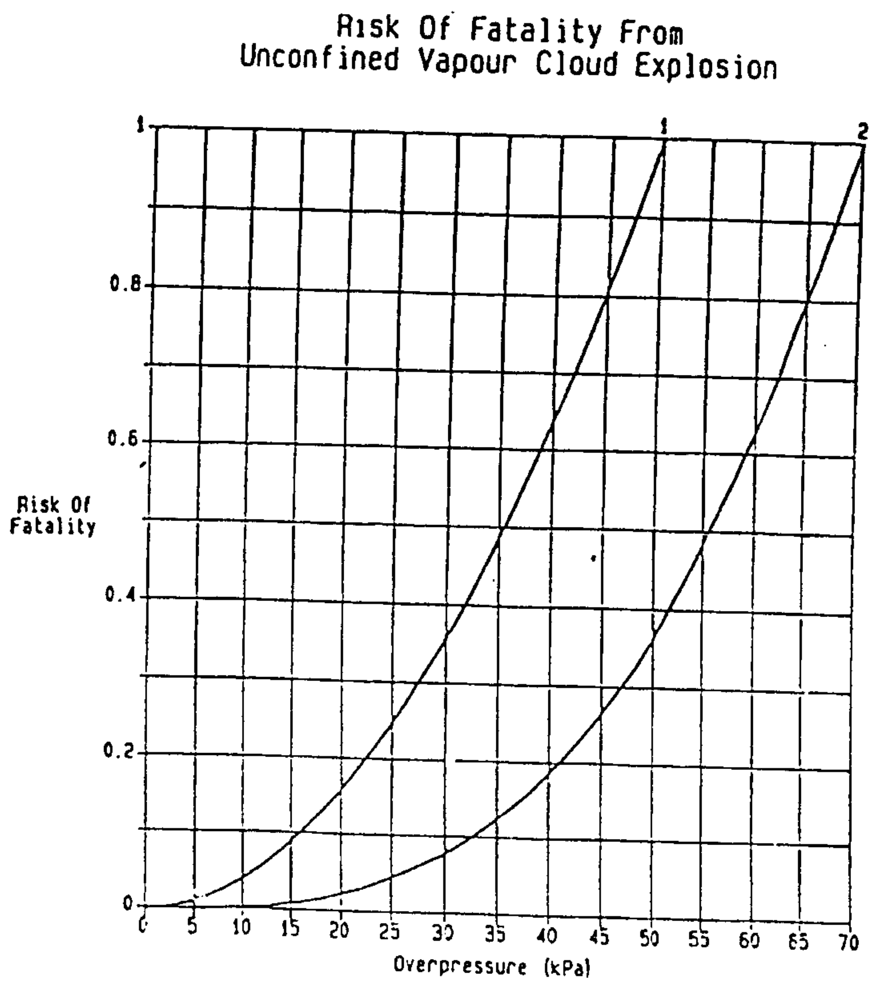
Maximum Overpressure in PSI (kPa)	Wind Velocity in mph (kph)
0.02 (0.14)	40 (64)
0.1 (0.70)	70 (112)
0.6 (4.20)	160 (256)
2.0 (14.0)	290 (464)
8.0 (56.0)	470 (752)
16.0 (112.0)	670 (1072)
40.0 (280.0)	940 (1504)
125.0 (875.0)	1500 (2400)

APPENDIX C

RISK OF FATALITIES OCCURING FROM A VAPOUR CLOUD EXPLOSION

The following graph graph shows the risk of fatality from an unconfined vapour cloud explosion.

Hazard Analysis Course Notes, ICI Engineering. 1988)



1 Person in conventional building

2 Person in open in chemical plant

Note : This is only a rough guide for use in the absence of better information

APPENDIX D

EFFECTS OF EXPLOSION OVERPRESSURE

The following table presents the effects of explosion overpressure.

TABLE EFFECTS OF EXPLOSION OVERPRESSURE

Explosion Overpressure	Effect
3.5 kPa (0.5 psi)	• 90% glass breakage • No fatality and very low probability of injury
7 kPa (1 psi)	• Damage to internal partitions and joinery but can be repaired • Probability of injury is 10%. No fatality
14 kPa (2 psi)	• House uninhabitable and badly cracked
21 kPa (3 psi)	• Reinforced structures distort • Storage tanks fail • 20% chance of fatality to a person in a building
35 kPa (5 psi)	• House uninhabitable • Wagons and plants items overturned • Threshold of eardrum damage • 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open
70 kPa (10 psi)	• Threshold of lung damage • 100% chance of fatality for a person in a building or in the open • Complete demolition of houses

Hazard Analysis Course Notes, ICI Engineering. 1988)

APPENDIX E

EFFECTS OF EXPLOSION OVERPRESSURE (2)

Information as supplied by Clete Stephan of MSHA (USA) to the Moura working group no.5 to be the levels used by them for fatalities caused by blast overpressure.

Explosive Force Expressed as Pressure in kPa	Effect
1	Ears pop
4	Glass breaks
7	Knocks person down
14	Trees blown down
35	Rupture ear drums
100	Damage to lungs
240	threshold of fatalities
340	50 % fatalities
450	99 % fatalities

APPENDIX F

EFFECTS OF OVERPRESSURE (3)

Based on observation made in Japan, various nuclear tests, experiments in shock tubes, high explosive tests and theoretical analysis the following effects (of value to this study) on structures of blast damage has been determined.

For certain structural elements with short periods of vibration (up to 0,05 second) and small plastic deformation at failure the conditions can be expressed as a peak overpressurp without considering the duration of the blast wave. These structure would be similar to the building of stoppings or walls without reinforcement or other methods in the underground environment. These structures fail in a brittle fashion and thus there is only a small difference between the pressure that cause no damage and those that cause complete failure.

Conditions of failure of overpressure sensitive elements.

Structural element	Failure	Approx. side-on peak overpressure in kPa
Glass windows, large and small.	Shattering usually, occasionally frame failure.	3.5-7
Corrugated asbestos siding.	Shattering.	7-14
Corrugated steel or aluminium panelling.	Connection failure followed by buckling.	7-14
Brick wall panel, 8 inch or 12 inch thick not reinforced.	Shearing and flexure failures.	21-70
Wood siding panels standard USA house construction.	Usually failure occurs at the main connections allowing the whole panel to be blown in.	3.5-7
Concrete or cinderblock wall panels , 8 inch or 12 inch thick (not reinforced.	Shattering of the wall.	10.5-38.5

TEST SUMMARY : Plain Concrete (1:2:4)

Material	Agency	Date	Passage Cross section	Stopping Thickness	Recesses	Appurtenances	Types of Explosion	Maximum Pressure on Stopping (psi)	Test Results
	USBM (Bureau of Standards)	1926	4ft x 4ft	8in	none	none	static pressure	10	Failed
				8in	restrained at ribs	none	black powder	107, 146	Withstood 107, failed at 146
				12in	unrestrained	none	static pressure	23	Failed
= 2500 psi	USBM (Experimental mine) Stopping 2	1928 - 1930	4ft x 7ft	19.2in	recessed 18in in each rib	none	black powder enclosed	up to 148	Remained intact
= 3300 psi	USBM (Experimental mine) Stopping 3	1928 - 1930	8ft x 7ft	12in	recessed 18in in each rib	none	black powder enclosed	up to 125	Remained intact
= 3300 psi	USBM (Experimental mine) Stopping 3A	1928 - 1930	8ft x 7ft	12in	recessed 4in in each rib	none	black powder enclosed	60	Cracks developed
								69	Cracks grew
								86	Stopping disintegrated
= 3300 psi	USBM (Experimental mine) Stopping 4	1928 - 1930	8ft 7in x 7ft 2in	12in	recessed 6in in each rib	none	black powder enclosed	42, 98, 100	At 100 psi, spalling occurred, leakage occurred at the roof and a large vertical crack developed
= 2500 psi	USBM (Experimental mine) Stopping 5	1928 - 1930	15ft 7in x 7ft 5in	12in	recessed 12in in each rib	none	black powder enclosed	175, 26.5, 35.5, 41, 55, 45	At 55 psi, leakage occurred at roof; and cracks at the edge of the inby face and the centre of the outby face indicated that strength had been exceeded. In the next test (45 psi) bulkhead failed completely
= 2000 psi	USBM (Experimental mine Stopping 6	1928 - 1930	12ft 8in x 6ft x 10in	9.5in	recessed 6in at each side	none	black powder enclosed	22	Bulkhead failed, forming central crack
= 3200 psi	USBM (Experimental mine) Stopping 7	1928 - 1930	16ft 3in x 6ft 10in	19.5in	recessed 7.7in at each rib	none	black powder enclosed	20, 36, 50, 55	Failed at 55 psi

TEST SUMMARY : Masonry and Composite Bulkheads

[illegible]aterial	Agency	Date	Passage Cross section	Stopping Thickness	Recesses	Appurtenances	Types of Explosion	Maximum Pressure on Stopping (psi)	Test Results
[illegible]sonry	ECCS (King Ludwig Mine)	1964 - 1965	43ft²	2.5ft	none	none	coal dust	27.4	Both bulkheads withstood all explosives
			135ft²	2.5ft				19.2	
	ECCS (Hagenbeck Mine)	1965 - 1968	134.5ft²	2.5ft (3 layer stone)	none	none	coal dust side on	>24	Survived 19.5 psi, failed at >24 psi
			134.5ft²	1.7ft (2 layer stone)	none	none	coal dust	25	Survived 15 tests up to 25 psi; failed No 17 at 18 psi
			64.5ft²	1.7ft (2 layer stone)	none	2.94ft x 6.6ft steel door	coal dust	22.5	Survived one test
	ECCS (Kaiserstuhl Mine)	1965 - 1968	107.6ft²	2.5ft (3 layer stone)	none	2.94ft x 5.24ft steel door	coal dust	30.5	Shifted slightly
	ECCS (Scholven Mine)	1965 - 1968	129ft²	1.7ft (2 layer stone)	none	steel door	coal dust	≤23	Withstood 11.6, failed at 23
[illegible]onry [illegible]crete [illegible]	USBM	1970 - 1971	14.5ft x 6.5ft	1.3ft	recessed 0.65ft into ribs: 1.0ft into floor	none	methane-air from 250ft side-on	≤48 psi 7.1 psi - sec	Withstood 9 blasts up to 48.5 psi
[illegible]posite [illegible]	ECCS (Tremonia Mine) wood-rock dust-masonry	1965 - 1968	9ft x 9.5ft	masonry 0.8ft rock dust 18ft	none	none	coal dust	≤11.6	Outby wood brattice destroyed at 11.6 psi
	masonry-rock dust-masonry	1965 - 1968		masonry 0.8ft rock dust 18ft	none	none	coal dust	≤62	Up to 41 psi, inby wall had slight deformation destroyed at 62 psi
	masonry-rock dust-masonry	1965 - 1968		masonry 1.7ft rock dust 18ft	none	none	coal dust	≤319	66.7, 151 psi without damage; slight deflection of inby wall at 160 psi; 0.65 ft deflection of inby wall at 319 psi
	ECCS (Dorstfeld Mine) masonry-rock dust-masonry	1964 - 1965	240ft²	masonry 2.5ft rock dust 4ft masonry 2ft	none	27in dia. pipe	methane-air at 250ft	4, 36, 19, 49	Bulged 8in in centre at 36 psi; moved an additional 2in at 49 psi

TEST SUMMARY : Gypsum

Material	Agency	Date	Passage Cross section	Stopping Thickness	Recesses	Appurtenances	Types of Explosion	Maximum Pressure (psi)	Test Results
Plaster of Paris w/s = 0.5	ECCS (Tremonia)	1961	86ft²	4.9ft	none	none	methane-air	55	Bulkhead undamaged
				9.8ft	none	none	methane-air	71	Bulkhead undamaged
w/s = 0.75	ECCS (Tremonia)	1965 - 1968	9ft x 9.5ft	10.8ft	none	none	methane-air	29, 54, 23	Bulkhead undamaged
w/s = 0.5	ECCS (Dorstfeld)	1964 - 1965	237ft²	8.2ft	none	none	methane-air	4	Bulkhead undamaged
								49	Failed after 0.5 sec
w/s = 0.75	ECCS (Dorstfeld)	1964 - 1965	237ft²	13.1ft	none	none	methane-air	30	Shattered at top, then repaired
								64	Completely destroyed
w/s = 0.68	ECCS (Kaiserstuhl)	1965 - 1968	151ft²	12.5ft	none	27in diameter ventilation tube		18.8	No damage
								23	No damage
w/s = 0.35 (with retarder)	USBM (Experimental Mine)	1970 - 1971	9ft x 6.5ft	2ft 3ft	none none		methane-air side-on	9 explosions maximum 48.5 psi 7.1 psi-sec	No visible damage. Air leakage not affected
			14.5ft x 6.5ft	4.6ft	none				
Hardstem	NCB (Welden Mine)	1965	10ft x 8 ft	10ft	none	27 in vent + instrument tubes	black powder and coal dust 30ft confined chamber	76 psi	No damage to bulkhead Ventilation tube hatch developed leaks
Saaralit	ECCS (Tremonia)	1965 - 1968	9ft x 9.5ft	3ft	none	none	methane-air	16, 58, 217, 275	Damaged at 275 psi
	ECCS (Scholven)	1965 - 1968	220ft²	5ft	none	none	methane-air	70	No damage
	EMC	1968	?	4.9ft	none	30in diameter vent tube		4 explosions 17.5 to 84	Slight damage seal intact
Anhydrite w/s = 0,36	EMC (Tremonia)	1968	108ft²	3.3ft	yes (22ft²)	none	methane-air 41in chamber in front of bulkhead	6 explosions from 21.8 to 261.5	Seal remained intact
	ECCS (Scholven)	1965 - 1968	194ft²	3ft	no	27in diameter vent tube	methane-air	to 65 psi	No damage
							coal dust	to 87 psi	

TEST SUMMARY : Cementitious and Miscellaneous Materials

Material	Agency	Date	Passage Cross section	Stopping Thickness	Recesses	Appurtenances	Types of Explosion	Maximum Pressure on Stopping (psi)	Test Results
Fly Ash-Cement 62% fly ash 7% cement 31% water	USBM (Experimental Mine)	1970 - 1971	14.5ft x 6.5ft	2.9ft 4.6ft	none	none	methane-air 250ft from bulkhead side-on	9 explosions up to 48.5 psi 7.1 psi-sec	Vertical crack occurred at 45 psi otherwise no damage
Rock Dust cement 48.5 tons rock dust 7.6 tons cement	ECCS	1961	86ft²	19.7ft	none	none	methane air 260ft from bulkhead	28 33 57	Failed tested a few hours after poured Undamaged, tested after a few days Undamaged - tested after 3 weeks
Reinforced Concrete 1660 < σ_c <3240 psi	USBM (Experimental Mine) Stopping 1	1923	4ft x 7ft	8.5in	1ft in each rib	none	black powder in closed chamber	34, 70, 297	Full length vertical crack
	USBM	1926	4ft x 4ft	8in	entire perimeter recessed ½ft simply supported	none	black powder closed chamber	46 76	Average maximum pressure resisted Average pressure causing failure
Sandbags (Jute sacks)	ECCS	1961	65ft²	8.2ft	none	none		20	Maximum safe pressure determined from earlier tests
	ECCS (Tremonia Exp Mine	1961	86ft	20ft	none	27in diameter vent tube	methane air from 260ft	43	Seal moved 8in and leakage occurred at the top
Brattice and Rock Dust	ECCS	1961	86ft	11ft	none	none	methane air from 260ft	14 and 28	Bulkhead disintegrated at both pressures

TEST SUMMARY : Cementitious and Miscellaneous Materials

Material	Agency	Date	Passage Cross section	Stopping Thickness	Recesses	Appurtenances	Types of Explosion	Maximum Pressure on Stopping (psi)	Test Results
<u>Fly Ash-Cement</u> 62% fly ash 7% cement 31% water	USBM (Experimental Mine)	1970 - 1971	14.5ft x 6.5ft	2.9ft 4.6ft	none	none	methane-air 250ft from bulkhead side-on	9 explosions up to 48.5 psi 7.1 psi-sec	Vertical crack occurred at 45 psi otherwise no damage
<u>Rock Dust-cement</u> 48.5 tons rockdust 7.6 tons cement	ECCS	1961	86ft²	19.7ft	none	none	methane air 260ft from bulkhead	28 33 57	Failed tested a few hours after poured Undamaged, tested after a few days Undamaged - tested after 3 weeks
<u>Reinforced Concrete</u> 1660 < σ_c <3240 psi	USBM (Experimental Mine) Stopping 1	1923	4ft x 7ft	8.5in	1ft in each rib	none	black powder in closed chamber	34, 70, 297	Full length vertical crack
	USBM	1926	4ft x 4ft	8in	entire perimeter recessed ½ft simply supported	none	black powder closed chamber	46 76	Average maximum pressure resisted Average pressure causing failure
<u>Sandbags</u> (Jute sacks)	ECCS	1961	65ft²	8.2ft	none	none		20	Maximum safe pressure determined from earlier tests
	ECCS (Tremonia Exp. Mine	1961	86ft	20ft	none	27in diameter vent tube	methane air from 260ft	43	Seal moved 8in and leakage occurred at the top
<u>Brattice and Rock Dust</u>	ECCS	1961	86ft	11ft	none	none	methane air from 260ft	14 and 28	Bulkhead disintegrated at both pressures

APPENDIX H

SUMMARY OF REFERENCES PUBLISHED BETWEEN 1981 AND 1993

Source : Contract Report No. BX2125600 5665. CSIR: Division of Building Technology, November 1995.

TEST SUMMARY : Solid concrete block seals

Bulkhead configuration	Nominal thickness inches (m)	Maximum overpressure psig (bar)	Impulse per area psi - s	Damage	Post explosion air leakage rates cft/min		Assessment (20 psig criterion)
					1 in water	4 in water	
Standard seal, thick wall, wetwall, pilaster, floor and rib keying	16 (0,4)	22 (1,52)	4,55	None	87	94	Passed
Thick wall, wetwall, pilaster, no floor keying	16 (0,4)	21 (1,45)	4,03	Large opening at roof, 2 large cracks at left outby side, bottom displaced about 1 in	NA	NA	Failed
Thin wall, wetwall, pilaster, floor keying, coating on inby side	8 (0,2)	19 (1,31)	2,98	All blocks removed except bottom row	NA	NA	Failed
Thin wall, wetwall, pilaster, rib and floor keying, coating on outby side	8 (0,2)	15 (1,03)	NA	Large crack at top, blocks missing on outby side, pilaster sheared off	NA	NA	Failed
Thick wall, wet wall, no pilaster, floor keying	16 (0,4)	17 (1,17)	3,74	Minor damage, stopping intact, mortar removed at top, some half blocks removed at roof line, approx 1ft² leak area formed	NA	NA	Marginal at <20 psig pressure
Thin wall, drywall, pilaster, rib and floor keying, coating on both sides	8 (0,2)	18 (1,24)	2,45	Destroyed, only a few blocks remained on and near ribs	NA	NA	Failed
Thick wall, drywall, pilaster, rib and floor keying, coating on both sides	16 (0,4)	20 (1,38)	3,17	All blocks removed except a few along both ribs and on floor	NA	NA	Failed

TEST SUMMARY : Cementitious foam seals

Material compressive strength psi (MPa)	Nominal thickness feet (m)	Maximum overpressure psig (bar)	Damage	Post explosion air leakage rates cft/min		Assessment (20 psig criterion)
				1 in water	4 in water	
200 (1,38)	8 (2,44)	29 (2,00)	None	0	31	Passed
200 (1,38)	4 (1,22)	22 (1,52)	Hairline cracks on inby side	52	114	Passed
100 (0,69)	4 (1,22)	22 (1,52)	Slight cracks, appearing continuous through seal	47	114	Marginal
50 (0,34)	8 (2,44)	21 (1,45)	Significant cracks on both sides of seal, having about ¼ inch gap	180	420	Failed
50 (0,34)	4 (1,22)	13 (0,90)	Seal was totally destroyed	NA	NA	Failed
208 (1,4)	4 (1,22)	26 (1,79)	none reported *	21	21	Passed
157 (1,1)	4 (1,22)	25* (1,72)	none reported *	21	60	Passed
376 (2,6)	4 (1,22)	22 (1,52)	none reported *	31	85	Passed
219 (1,5)	4 (1,22)	22 (1,52)	none reported *	52	152	Passed
168 (1,2)	4 (1,22)	21 (1,45)	hairline cracks, appearing to extend through seal	61	154	Marginal

* results are stated to be valid only for 125 ft^2 (11,6 m^2) or smaller openings larger openings said to require either higher strength material or be thicker

TEST SUMMARY : Low density, glass-fibre reinforced, foam blocks

Number and size of pilasters see note *	Nominal thickness feet (m)	Maximum overpressure psig (bar)	Damage	Post explosion air leakage rates cft/min		Assessment (20 psig criterion)
				1 in water	4 in water	
2 of 48 inches x 48 inches	2,7 (0,82)	20 (1,38)	no damage reported	21	52	Passed
2 of 48 inches x 48 inches	2,0 (0,61)	21 (1,45)	none reported, but some damage implied in results	140	294	Marginal
1 of 56 inches x 72 inches	2,0 (0,61)	20 (1,38)	no damage reported	39	87	Passed
1 of 48 inches x 48 inches	2,0 (0,61)	19 (1,31)	no damage reported	63	139	Passed

* All seals had special mortar joints, with rib and floor keying, with a fibreglass reinforced coating on both sides

TEST SUMMARY : Cementitious foam seals

Material compressive strength psi (MPa)	Nominal thickness feet (m)	Maximum overpressure psig (bar)	Damage	Post explosion air leakage rates cft/min		Assessment (20 psig criterion)
				1 in water	4 in water	
200 (1,38)	8 (2,44)	29 (2,00)	None	0	31	Passed
200 (1,38)	4 (1,22)	22 (1,52)	Hairline cracks on inby side	52	114	Passed
100 (0,69)	4 (1,22)	22 (1,52)	Slight cracks, appearing continuous through seal	47	114	Marginal
50 (0,34)	8 (2,44)	21 (1,45)	Significant cracks on both sides of seal, having about ¼ inch gap	180	420	Failed
50 (0,34)	4 (1,22)	13 (0,90)	Seal was totally destroyed	NA	NA	Failed
208 (1,4)	4 (1,22)	26 (1,79)	none reported *	21	21	Passed
157 (1,1)	4 (1,22)	25 (1,72)	none reported *	21	60	Passed
376 (2,6)	4 (1,22)	22 (1,52)	none reported *	31	85	Passed
219 (1,5)	4 (1,22)	22 (1,52)	none reported *	52	152	Passed
168 (1,2)	4 (1,22)	21 (1,45)	hairline cracks, appearing to extend through seal	61	154	Marginal

* results are stated to be valid only for 125 ft^2 (11,6 m^2) or smaller openings
larger openings said to require either higher strength material or be thicker

TEST SUMMARY : Low density, glass-fibre reinforced, foam blocks

Number and size of pilasters see note *	Nominal thickness feet (m)	Maximum overpressure psig (bar)	Damage	Post explosion air leakage rates cft/min		Assessment (20 psig criterion)
				1 in water	4 in water	
2 of 48 inches x 48 inches	2,7 (0,82)	20 (1,38)	no damage reported	21	52	Passed
2 of 48 inches x 48 inches	2,0 (0,61)	21 (1,45)	none reported, but some damage implied in results	140	294	Marginal
1 of 56 inches x 72 inches	2,0 (0,61)	20 (1,38)	no damage reported	39	87	Passed
1 of 48 inches x 48 inches	2,0 (0,61)	19 (1,31)	no damage reported	63	139	Passed

* All seals had special mortar joints, with rib and floor keying, with a fibreglass reinforced coating on both sides

APPENDIX J

PROPOSED CONCEPTUAL DESIGNS FOR THE CONSTRUCTION OF REFUGE BAY BULKHEADS
(Capita Selecta from Contract Report No. BX2125600 5665. CSIR: Division of Building Technology, November 1995, and further correspondence with Dr. B.L. Lunt of Boutek.)

1.0 INTRODUCTION

Lunt and Barker, on behalf of Miningtek, devised design proposals for the designs of refuge bay bulkheads according to South African standards. Initially doubts were expressed about the validity of the strength requirements as determined by the specified overpressures and pulse lenghts. The original explosion characteristics, hoever, are so similar to those proposed by this study as well as those used by the USA and Australia that these designs can be considered to be quite valid for use in local conditions. This appendix sets out a capita selecta of the presented report. the designs and motivation of the design principles used.

2.0 Background

A literature survey indicated that there are several tried and tested bulkhead construction methods used overseas that could be used as a guide in local refuge bay construction. The established forms of construction of interest to this project were essentially of two kinds, namely mass plugs and heavy wall constructions.

Discussion with one of the modern mines (Khutala) indicated that these forms of construction could be followed and in addition, because of the experience and practices relating to ventilation stoppings and other wall constructions, two further options would be viable as well.
The discussions at Khutala regarding constraints within the mine, that might influence forms of construction, revealed that in a modern mines there were in fact few serious constraints.

5.2 Constraints in the mine

The possible constraints associated with materials handling, equipment, manpower and construction time were discussed at Khutala. It has been concluded that in a relatively modern mine there would be very few restrictive constraints on materials and equipment as vehicular transport of materials such as cement, aggregates, concrete blocks and equipment could be readily accommodated and mixing water for concrete would be available.

5.2.1 Materials

Materials such as in-situ concrete, shotcrete and solid concrete blocks, are frequently used. Dump rock was generally not available and fragmented rock and coal was not suitable as it was brittle and contained pyrites.

5.2.2 Materials handling

The main requirement would be that objects be of a size and mass that would allow them to be man-handled, for example, conventional large sized concrete blocks and 20 litre drums would be ideal from a handling point of view. Large drums such as 44 gallon drums would be difficult to handle and therefore unsuitable. Transport of cement and concrete aggregates would not pose a problem and reinforcing mesh for shotcrete is commonly used. Containerised transport of 8 ton and 3 ton sizes can also be accommodated in certain mines; in others the mass may need to be limited to a half a ton.

5.2.3 Equipment

Any equipment that is transportable on a small truck may be used in a mine like Khutala. Appropriate electrical equipment is also used.

5.2.4 Time restrictions

At Khutala it was not considered essential to be able to construct a wall very rapidly and a five day construction period with a longer curing period would be regarded as acceptable. (It was said that equipping the refuge bay could take about two months, in relation to which the construction time was not too critical.)

5.3 Proposed refuge bay construction methods

In all of the forms of construction described below, except for the options using roof trusses, it is essential that the base and sides of the bulkhead are keyed (recessed) into the floor and ribs. (Bulkheads required to withstand the horizontal force of a blast wave would ideally be keyed into all the surrounding rock-faces - footwall, hangingwall and ribs, but keying into the hangingwall may be difficult to achieve in practice.) The proposed designs are all for an opening nominally 6 m wide and 3,5 m high, with a 1,8 x 0,9 m doorway and two 150 mm diameter vent holes, as indicated in Figure 2. Figures 3 to 7 illustrate the conceptual designs and give constructional details.

The parameters of importance in selecting materials for evaluation to provide low strength, bulky structures for refuge bay enclosures are cost, strength, durability and absence of noxious effects under both normal and disaster circumstances. The criteria for strength and durability are not extreme (strength requirements being low for mass plugs) and, while durability can be a serious problem for concrete in a coal mine, the relatively short service life for a refuge bay reduces the importance of this aspect of performance to a degree.

5.3.1 Mass plug type of bulkhead

These are plugs made of materials that cen be cast in place, preferably by pumping the wet mix between the most convenient kind of formwork. At this stage, the two materials regarded as most appropriate are foamed concrete (with minimum aggregate content) and stabilised fly-ash (for collieries with nearby power stations as a source of fly-ash).

Where major power generating facilities are situated close to the mines for which refuge bays are required, ash can be utilised for low strength, bulky structures. Test data for mixes incorporating ash and different forms of stabiliser/activator for the ash which are being investigated are tabulated below. These details pertain to the second series of mixes which adopted the most promising of the binder systems identified in the initial tests but allowed for by-product rather than the commercial form of activator in one instance and extended the series to include coal in the mixes to simulate the use of mine waste.

Flyash	Cement	Slagment	Hemi Hydrate	Gypsum	Coal	7 Day Str MPa	28 Day Str MPa
100		4	4			0,4	0,8
100		4		4		0,5	1,3
100		8	8			0,5	1,9
100		8		8		0,5	1,8
100	8					1,1	1,7
100	16					2,7	4,5
50		4	4		50	0,4	0,9
50		4		4	50	0,4	1,1
50	8				50	2,1	3,3

The mixes are described in terms of the ratios of the constituents, and with the density of the principally flyash mixes being of the order of 1 500 kg per cubic metre and the water contents of these mixes being 350 litres per cubic metre, actual masses per cubic metre are approximately tenfold the values tabulated. The mixes with a blend of coal and flyash are moderately denser and had lower water contents so the multiplier is approximately twelve for the tabulated figures to covert to quantities per cubic metre. Final quantities will vary slightly from

these approximate values depending upon the mix consistency as dictated by construction practice and depending upon the mix constituent ratios.

In addition to strength tests on the mixes as tabulated above, specimens have been stored partially immersed in coal mine water for four months with no evidence of deterioration during this period. Approximate stress strain relationships to failure have also been recorded for all nine combinations of material. It is worth noting that while the mixes incorporating coal did not display any improvement in strengths relative to those with the total "filler" consisting of flyash as would have been expected from the lesser water requirements, they did display a capacity to sustain a high proportion of the failure load as deformation was continued. This could be a highly useful attribute in the field if several successive explosions occurred.

For relatively small openings, in the order of 4 m x 2 m, these plugs could be between 1,2 m and 1,3 m thick, for material compressive strengths of 1,5 MPa and 1,0 MPa respectively, based on reported test data. For larger openings, such as seen at Khutala, up to about 6 m x 4 m, the required thickness of the plug is suggested at (height of opening)/1,6 to (height of opening)/1,5 for a material strength of 2 MPa. See Figure 3 for typical details.

The option for construction shown in Figure 3 is a very thick barrier of unreinforced low strength cementitious material such as foamed concrete. This is essentially the same kind of stopping that has been used in Europe, cast in Gypsum and the cementious foam seals tested in the USA. These stoppings work in the same way as a plug in a basic and because they are typically unreinforced and of large thickness they have been referred to as mass plug types. This type of bulkhead or stopping has been shown in full scale tests to work well under moderate to very high blast pressures in relatively small tunnel cross sections (between 8 and 20 m^2).

The thickness of 2-3 metres suggested in Figure 3 for the range of compressive strengths between 1 and 2 MPa are considered to be adequate to resist the relatively low over pressure of 1 bar specified in the brief. Because only very low material strengths are needed, it is possible to utilise pumped foamed concrete successfully. The mass plug may be considered viable because it is a simple structure, easy to build and requiring only the raw materials and unsophisticated formwork such as rough timber. The only equipment required that may not normally be found in coal mine would be a mortar/concrete pump.

5.3.2 Hybrid type bulkheads

Two forms of "hybrid" bulkhead have received attention, one having a foam concrete or other low strength concrete core with reinforced gunite outer layers, the other consisting of two solid concrete block walls with a concrete core containing roof trusses.

The conceptual design of the first hybrid bulkhead consists of 60 mm to 80 mm thick gunite outer layers, reinforced with a heavy mesh (9 mm diameter at 200 mm centres) or Y10 bars at 300 mm centres, with additional reinforcement around the door opening. The core would consist of 2 MPa foam concrete about 1 metre thick to give an overall thickness of 1,1 to 1,2 metres for the bulkhead. See Figure 4.

The form of construction illustrated in Figure 4 of BOU/C29 is called a hybrid because it combines the use of both low strength and reinforced high strength concrete in a fairly thick composite wall. Because of the thickness of this wall, its structural behaviour combines flexural resistance with internal arching action. The idea of using this type of construction was prompted by the observation of the use of reinforced gunite (shotcrete) at Khutala mine.

The construction of such a bulkhead would be in two stages. The first stage would be casting of the low strength core material between rough shuttering which would be removed before fixing the reinforcement of the outer layer that would be completed with gunits. It is essential that the steel links between the two outer layers be provided throughout the bulkhead. The core material could be the same foam concrete as used in a mass plug bulkhead.

The advantage of this form over the mass plug would be the smaller volume of aggregate required and the more durable surfaces of the bulkhead.

The second conceptual design consists of two 200 mm thick solid concrete block walls spaced about 300 mm apart, with a 20-25 MPa concrete core. The core would contain trusses spanning horizontally above door height and trusses would be installed vertically on either side of the doorway. 8 mm diameter ties would be built into every second course of the blockwork walls at horizontal spacings of 500 mm, to link the two walls together. See Figure 5.

This form of construction illustrated in figure 5 of BOU/C29 makes use of a combination of solid concrete blockwork walling and pre-tensioned anchor trusses that are well known in the mines. It combines the structural resistances of regular solid concrete black walls with the strengthening effect of a tensioned net created by the trusses. The overall thickness of this type of wall would be somewhat less than the type 1 hybrid and keying into the floor and ribs is considerably aided by the anchorage or the trusses into the root, floor, and ribs.

5.3.3 Heavy wall type bulkhead

This is essentially a wall based on the American "standard" bulkhead built of solid concrete blocks, stiffened with one or more pilaster.

For relatively small openings, in the order of 4 m x 2 m, these bulkheads could feasibly be built exactly like those tested by the USBM. These bulkheads were 406 mm thick with a single centrally located 812 mm pilaster. For larger openings it would be necessary to have more pilasters, with as many as three for openings of about 6 m x 4 m. It would be important that quality control on the construction of such bulkheads was good. Also, keying of the pilasters to the floor and roof would be essential.

The heavy masonry bulkhead illustrated by Figure 6 of BOU/C29 is based directly on the descriptions of solid concrete block masonry referred to in the USA literature as a standard type seal and on the structural principles for the design of load-bearing masonry. The design shown in the report makes-use of the horizontal spanning capability of masonry between vertical restraints, which in this case are provided by the recess into the ribs and floor and by the heavy pillars (pilasters in American terminology) which limits the magnitude of the horizontal spans.

The use of fully bonded solid concrete block masonry was regarded by the American mines as the most convenient method of construction, probably because of the availability of blocks and of block-laying skills. The large size of blocks generally used makes it possible to build a wall very rapidly, but it must be emphasised that in order to be successful, all the bedding and perpend joints must be completely filled with mortar of good quality.

The structural action is regarded as largely the arching action that does develop in masonry which is restrained against in-plane movement at its perimeter.

One of the advantages of this form of construction is the ease of transport of the basic construction components.

5.3.4 Reinforced concrete bulkhead

This form of construction, shown in Figure 7 in the report, is commented on ahead of the two hybrid forms, because it will make the term hybrid type easier to understand.

This type of bulkhead corresponds to the slender wall bulkhead referred to in our report of November 1994. The conceptual design consists of a 400 to 450 mm thick reinforced wall of 25 MPa concrete with a layer of reinforcement near each face. The reinforcement would be 20 mm diameter bars at 250 mm centres in the vertical direction and 16 mm diameter bars at 400 mm centres horizontally when all edges are keyed in recesses. The two layers of reinforcement would be linked by sets of closely spaced stirrups and additional reinforcement would be required around the doorway. Figure 7 shows reinforcement details for two kinds of main reinforcement.

The design shown in Figure 7 is a moderately thick wall made of reinforced concrete which resists lateral loading such as blast pressures by virtue of its flexural strength. It acts in the same way as a suspended reinforced concrete floor, of a building, which is supported at its edges. The volume of 25 MPa concrete in this type of wall would be about 1/5th of the volume of 2 MPa material in a mass plug type of wall, but it has two layers of steel reinforcement in it wherever the mass plug has no reinforcement. The reinforcement concrete type of wall would be suitable in mines where reinforced concrete is a familiar construction material underground. The concrete could be either conventionally placed and compacted or pumped generate could be used.

5.4 Steel doors

An important item to be considered is the access door to a refuge bay through the bulkhead. The door opening considered would have a height between 1,5 and 1,7 metres, a base width of 900 mm and a top width of 800 mm with the hinged edge sloping and the opposite edge vertical, following the same pattern as currently in use at Khutala, if the self-closing action is required. Alternatively, the door opening could be a right rectangle of 800 mm width and the hinges could be offset at an angle to give a self-closing action.

Two options for the steel self-closing doors to be fitted to bulkheads have been considered. The first option for door construction would be a flat steel plate of substantial thickness. For the proposed door opening size a flat plate of 12 mm thickness would be required, which is very heavy (145 kg). The second option is a fabricated light sheet steel door that is fairly light in comparison (56 kg). This type of door consists of a thin curved steel plate, 1 mm thick, with concave surface facing the blast overpressure, with a stiffening frame around the perimeter. See Figure 8.

The pros and cons of these doors are:

The heavy door is simpler and therefore probably cheaper than the light weight door, but would be more difficult to open and very substantial well anchored hinges would be required. The light weight fabricated door would be easier to operate and require lighter hinges, but will need to be built by a specialist fabricator and may be more expensive.

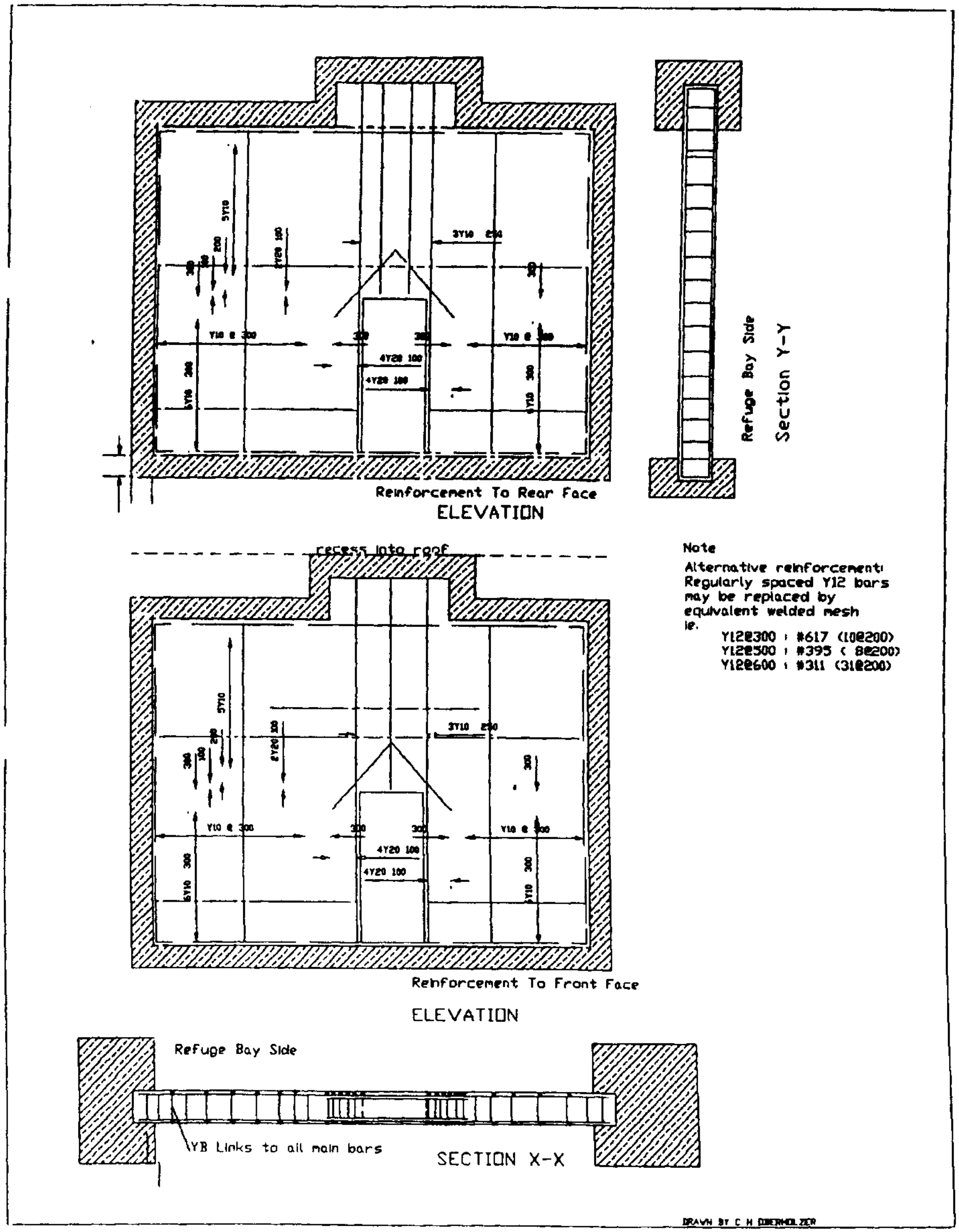
For both types of door, a steel door frame should be built into the bulkhead. It could consist of moderately heavy angle iron and be well anchored into the wall. If fully airtight closing is a real requirement, then elastomeric seals would be necessary around the perimeter, between the door and the frame as indicated in Figure 8.

5.5 Ventilation holes through bulkhead

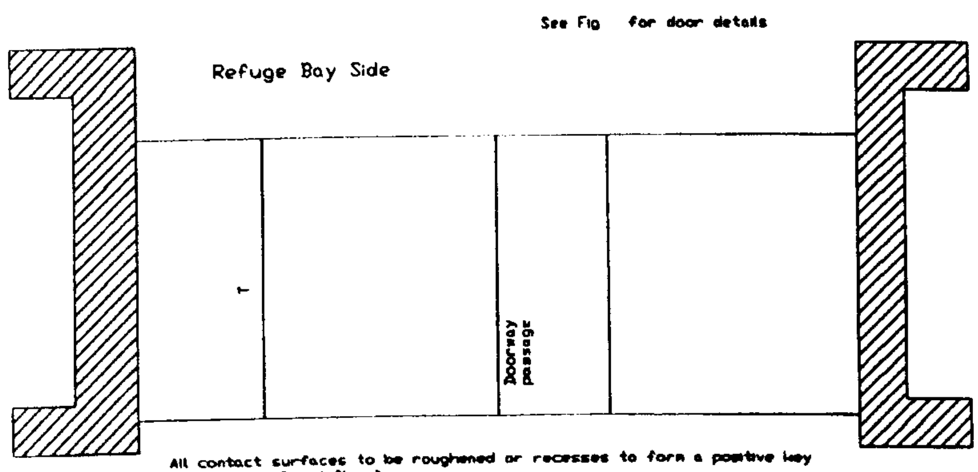
It is understood that permanent ventilation holes through the bulkhead will be required. Provided these are of roughly circular cross-section and not more than about 150 mm in diameter, such holes should not have any practical influence on the structural capability of the bulkhead designs proposed.

6 LOCATION OF BULKHEAD WITHIN EXCAVATED OPENING

The face of the bulkhead subject to blast pressure should be built as close to the tunnel wall as practicable (nominally flush with the tunnel wall) to avoid the unfavourable pressure increases that can develop in a recess through reflected wave effects.



Reinforcement To Rear Face
ELEVATION
Refuge Bay Side
Section Y-Y
recess into roof
Note
Alternative reinforcement:
Regularly spaced Y12 bars
may be replaced by
equivalent welded mesh
ie.
Y12@300 : #617 (10@200)
Y12@500 : #395 (8@200)
Y12@600 : #311 (3@200)
5Y10
3Y10 @ 250
Y10 @ 300
4Y20 100
300
Reinforcement To Front Face
ELEVATION
Refuge Bay Side
Y8 Links to all main bars
SECTION X-X



All contact surfaces to be roughened or recesses to form a positive key (including roof and floor)

Thickness of bulkhead for different material compressive strength

Compressive strength MPa	Thickness "T" M
1.0	2.8
1.5	2.2
2.0	1.9

Figure 3 Sectional plan of mass plug bulkhead

DRAWN BY C H OBERHOLZER

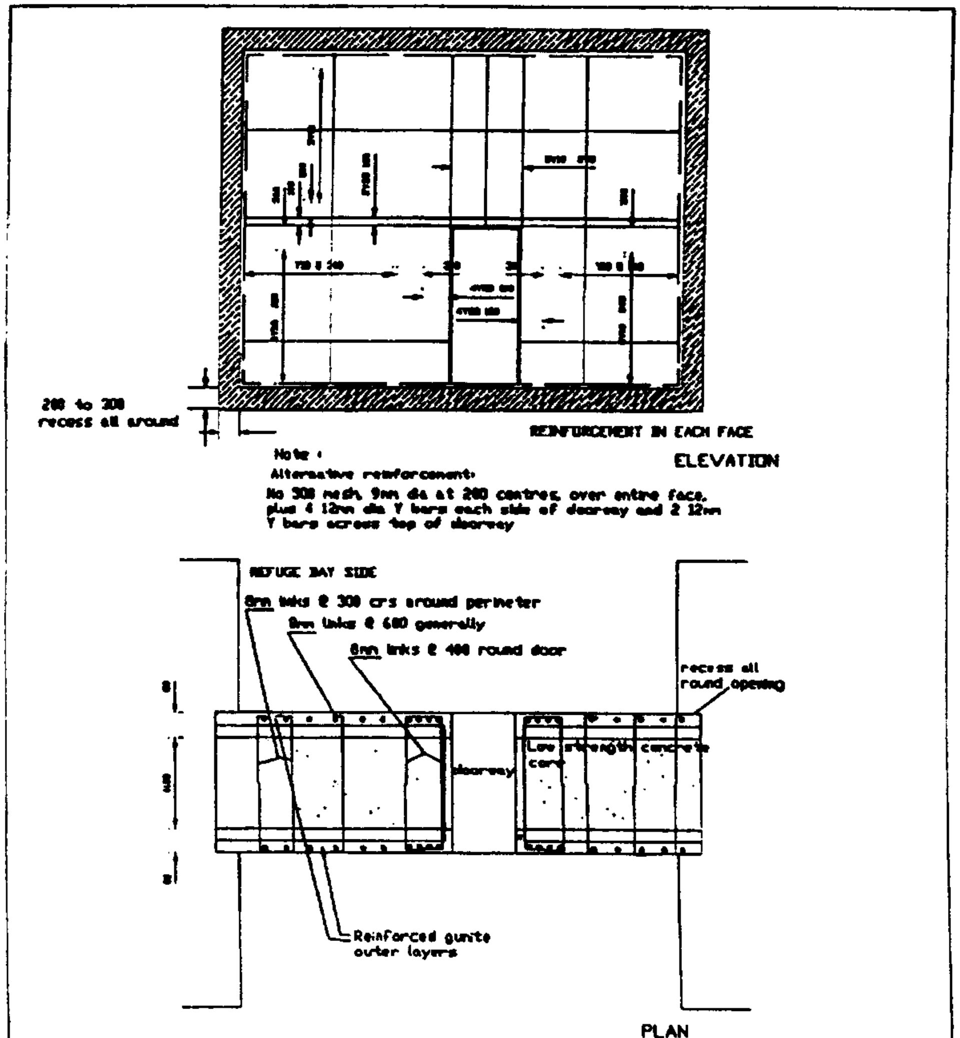


FIGURE 4 HYBRID BULKHEAD TYPE 1

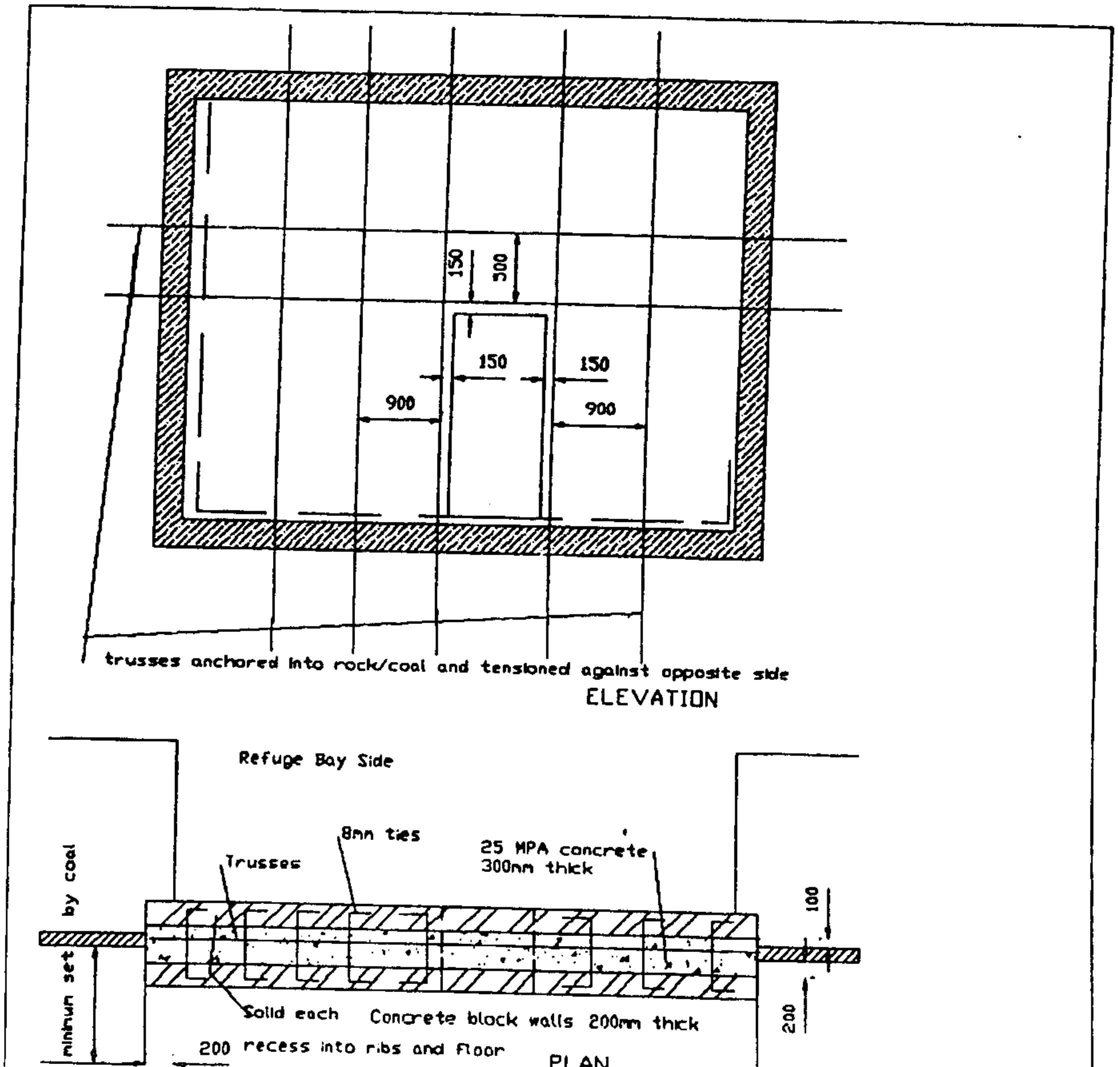


Figure 5 Hybrid bulkhead Type 2

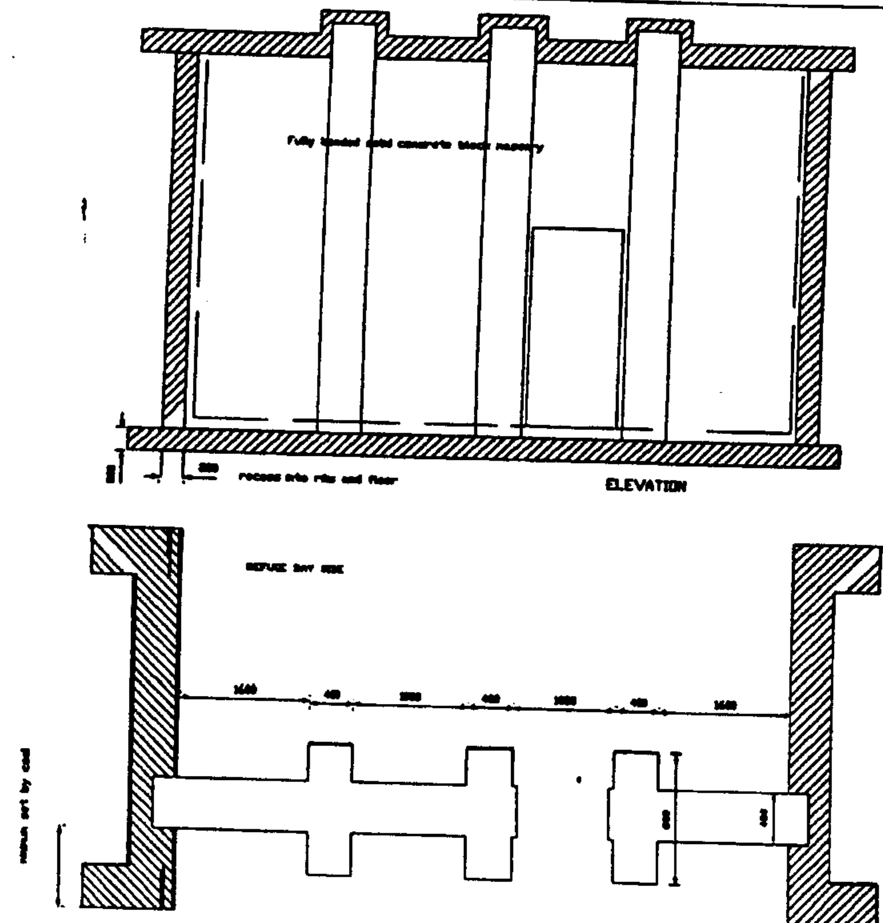
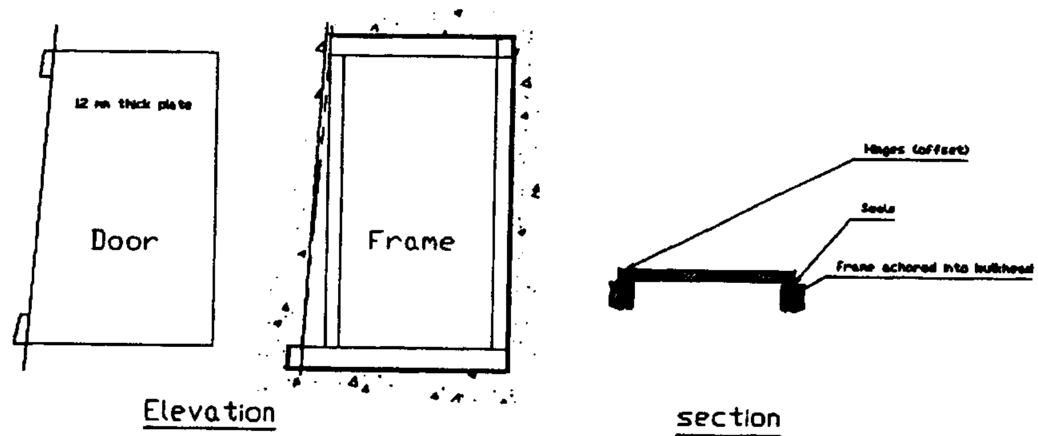


Figure 6 Heavy masonry cell

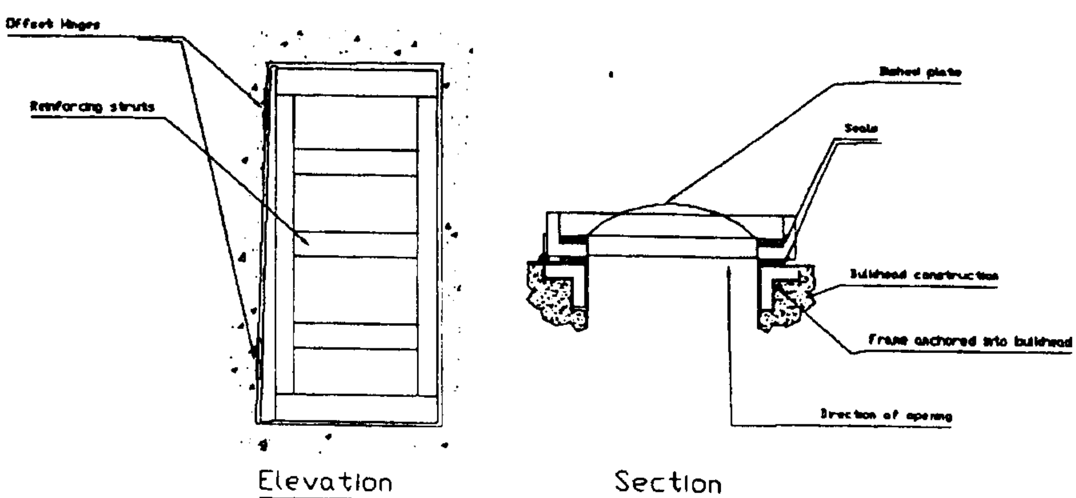
HEAVY FLAT STEEL DOOR



Doors open outward on offset hinges.
Force of explosion presses door against
frame and seal. Frames anchored into
bulkhead construction.

LIGHTWEIGHT
FRAMED STEEL DOOR

Angle-Iron Frame
dished plate covering.



Door in frame

Not to scale

FIGURE 8 STEEL ACCESS DOOR

APPENDIX K

PROPOSED OUTLINE OF ALTERNATIVE STRATEGY FOR THE USE OF REFUGE BAYS

A change in the present strategy for affording workers safety in the aftermath of an explosion or fire has been identified. This change is due to the following issues identified during the execution of this project.

1 It is doubtful if a present day mine would be able to keep a refuge bay, in the traditional sense, within 500-600m from the working face.
2 The incidence of building fully equipped refuge bays due to "required" distance is too high to be practical for mines.
3 The practical distance that would be required is significantly less than the "required" distance. This is due to the width of the sections involved. For example to maintain a 600m distance for a longwall the refuge bay would have to be kept within 400m from the maingate when the face width is in the order of 200m. This would mean that for a 2km panel ther would have to be 5 fully equipped refuge bays.
4 The closer to the face the stronger the structure needs to be. This increases the time rquired to establish such a bay as well as the costs to build such a structure.
5 There are serious implications with regard to the surface installations especially if the surface rights do not belong to the mine.
6 The duration of the selfcontained selfrescuers cannot be increased due to the fact that the mines have already invested significant amounts to provide them to workers.

PROPOSED STRATEGY

The rescue of workers in the aftermath of an incident should be divided into two phases. The first phase is where a principle of self rescue applies. The second part is where the rescue effort will be assisted by efforts and infrastructure from the mine.

Self Rescue phase.

The thirty minute selfcontained self rescuer is used to reach a safe haven within easy reach of the set. This means that this haven must be within the range of the set when used in a sitauation of no visibility. It can be assumed that no direct guidance can be afforded to this safe haven and workers would have to reach this point based on their familiarity of the section and where this haven is placed.
This place or haven should be so designed that;

1 It is quick and easy to construct, less than a day.
2 It should have a contained method of providing air or oxygen for an intermediate period .
3 It should not be incapacitated by the explosive forces although it need not withstand them.

(Further work should be done to enable such systems to survive explosion effects rather than witstand them.)

4 The support system in this haven should be directed at supplying isolation from poisonous atmospheres and provide life sustaining first-aid only.

5 The main purpose of this have will be to workers suffering from the effects of an incident a place the know they can reach, a place where they can regroup and consolidate befor venturing out to a place of safety amd from where they know there is infrastructure to allow them to reach this place of safety.

6 Stored in this haven will be a method that will allow the worker to travel to this further refuge bay where he can saty for extended periods.

Assisted Rescue Phase

After those that were able to reach the safe haven have consolidated their position and hace waited a long enough time to be sure that those who could reach the haven would have done so they can move out to the more permanent refuge bay. Movement to this bay will be done under the following general conditions.

1 The movement of workers will be done using established infrastructure that will enable them to reach the refuge bay even in conditions of zero visibility.

2 The infrastructure should be such that it will enable all workers to reach this refuge bay.

3 This infrastructure should be such that it will survive the effects of an explosion and be usable after such an incident.

4 The route followed should be such that it does not hamaper the progress of workers to the refuge bay.

5 The air supply given to workers should be such that it will allow workers to reach the refuge bay with a level of safety built in.

The requirements for the refuge bay in this second phase would be the same as for the present refuge bays.

The effect of this altered strategy is thus to assist the workers to negotiate the distance between the working place and the refuge bay by introducing an additional stage which can be reached and where they can obtain an air-supply to travel the longer distances. From this point there will also be a clear indication of how to reach the refuge bay.

DOCUMENT 2

SIMRAC

A MANUAL FOR BEST PRACTICE FOR EMERGENCY RESPONSE PROCEDURES

PART 2

THE MANAGEMENT OF INRUSHES, FIRES, EXPLOSIONS AND OTHER EMERGENCIES

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Research Agency: Turgis Technology (Pty) Ltd.

Project No. COL 605
Date: February 2000

Table of Contents

1 Introduction

With the exception of those incidents that are solely attributable to nature, virtually all other incidents, the hand of man can usually be detected to a greater or lesser degree. It would be fair to say that if the myriad of laws, regulations, standards and Codes of Practice that govern mining operations were scrupulously adhered to, there would be very few untoward incidents.

However, in reality, one must anticipate that, at times, things will go wrong and some times they will go badly wrong. It is therefore prudent that mine management, having done their best to prevent an incident occurring to begin with, have in place plans, facilities and equipment to manage the situation when the incident occurs. This is achieved by introducing and rigorously enforcing a system of Hazard Identification and Risk Assessment right down to the individual sections. Thereafter putting in place appropriate and if necessary, site specific Emergency Response Strategies and Procedures.

By having a plan of action, facilities, all the necessary equipment in place, and a management team familiar with what they are required to do, the handling of any situation becomes much easier and the consequences of the incident invariably much reduced.

What has become apparent, is that a major programme of quality assurance is necessary to ensure that the standards, Codes of Practice and regulations are diligently put into practice, thus minimising the chances of a disaster.

2 Escape and rescue

Escape and rescue can be categorised into six sections:

- Pre-planning.
- Awareness of the emergency situation.
- Self rescue procedures - Self Contained Self Rescuers (SCSR).
- Locating and reaching a place of safety.
- Refuge bays.
- Training.

The following should be considered "Emergency Situations"

- Fire.
- Explosion.
- Smoke detected by sight or smell.
- CO concentrations in excess of 100 ppm in the general body of the air.
- Flammable gases in an explosive concentration in the general body of the air.
- Suspected irrespirable atmosphere.

The essential constituents of a comprehensive escape and rescue strategy are discussed further as follows:

2.1 Emergency response strategy

In order to deal with any emergency effectively it is essential that everyone involved, from the workforce underground to the Mine Manager, know what is expected of them. There should be in place a formal document detailing the emergency response strategy for *every* working place / section covering:

- The location of the workforce.
- Their escape route(s). (Shown on plan).
- Instructions for reaching safety.
- Details of the refuge bay or place of safety .
- Telephone numbers in the section and in the refuge bay or place of safety.
- The number of persons likely to be involved.
- Names and positions of the supervisors from Miner upwards.

This document requires updating at regular intervals and at any time that the section moves or any significant or relevant changes are made involving the section.

A copy should be posted up at the waiting place and switchgear of every section as well as at workshops, stores etc. All affected workers should have the escape and rescue procedure explained to them in the course of escape drills.

A copy should be kept in the Emergency Control Room and the original document kept securely in the ventilation department.

This document should be drawn up by the responsible production officials in consultation with the ventilation department and countersigned by all relevant parties.

2.2 Emergency awareness

Apart from those situations where the emergency situation is detected by the human senses, detection by electronic instruments and by the raising of an alarm must also be considered.

Electronic instruments: The specification, maintenance, deployment and issuing of electronic instruments are catered for in the guidelines for Codes of Practice for Lamprooms issued by the DME and by statutory requirements. It is advisable that persons are issued with individual gas detection instruments and that a quality assurance programme for checking their operation by the issuers and users should be put in place.

Suitable means of raising the alarm in the event of an emergency should also be used. SIMRAC Report GEN 101 is of the opinion that a telephone system is inadequate for this purpose and that manually activated sirens located at the section switchgear or other such means should be considered.

It is imperative that all employees are aware of Emergency Procedures and what to do in the event of an emergency. This must be included in the training of all employees and reinforced on their return from leave.

Regular and documented drills need also to be carried out to ensure the competence of all employees in their different situations.

2.3 Self contained self rescuers (SCSRs)

It is a statutory requirement that all persons going underground in a colliery be equipped with a SCSR and trained in its use.

The type, capacity, storage, issuing, monitoring and maintenance of SCSRs are the subject of Codes of Practice, DME guidelines and statutory requirements.

It is most important to have in place a monitoring protocol for SCSRs. The efficiency and reliability of SCSRs can deteriorate depending on age and the conditions to which they have been subjected. By having a defined, statistically reliable, independent testing and evaluation programme, problems can be detected and appropriate measures introduced.

Reliable checking and maintenance of SCSRs in conjunction with the Original Equipment Manufacturers is also a requirement. In addition a good record keeping system tracking the history of maintenance, issuing and use of individual SCSRs should be in place. Computer programs are available for this purpose.

When caches of long duration SCSRs are used, a suitable programme of monitoring and recording their condition and disposition should also be put in place. Having long duration SCSRs available does not however relieve the mine of its obligation to supply belt worn SCSRs to each person underground.

SCSRs should be deployed by persons underground when:

- CO concentration exceeds 400 ppm in the general body of the air.
- Smoke is detected visually.
- Any time an irrespirable atmosphere is suspected.
- When instructed to do so by a supervisor.

2.4 Locating and reaching a place of safety.

Due to the strong likelihood of low visibility, disorientation and psychological trauma that can exist following a fire or explosion in a colliery, it is imperative that adequate provision be made to ensure that affected persons reach a place of safety. This requires that persons are trained in the use of and have available a suitable means of physically guiding them to the refuge bay or place of safety. The best means of doing so is a rope or wire fitted with cones to indicate the direction of travel placed along the route, against the pillar or sidewall, about 800 mm above the ground, that leads directly to the refuge bay door or other place of safety. Black PVC pipe with wedges cut out at 1 – 2 m intervals indicating the direction of travel has also proved successful.

There can be no gap in this route and therefore any place that persons who are trying to find their way in zero visibility could get lost or take a wrong turning must be catered for. Such areas must be barricaded off to prevent inadvertent entry. When conveyor belts are to be crossed over, suitable bridges must be provided.

SIMRAC Report GEN 101 "Practices and Procedures to Overcome Problems Associated with Disorientation and Low Visibility in the Aftermath of Mine Explosions of Fires" investigated some of these problems and the following highlights are extracted directly from this report:

(a) "the speed at which escape routes can be negotiated is reduced significantly irrespective of audible orientation cues; obviously safe travelling distances from the area of work to a back-up facility would have to be adjusted accordingly,

(b) some form of support to assist the escapee to maintain his equilibrium, especially in the case of obstacle ridden escape routes, and to avoid injury appears to be crucial; the incorporation of a direction guidance system represents a further element of importance,

(c) belt roads, although regarded as generally suitable, should not be regarded as a dedicated primary escape route,

(d) the pinpoint location of refuge rays and refuge bay entrances in the event of real emergencies appears to have been underestimated severely by planning departments."

and

- "that a guidance rope or cable be installed along dedicated escape routes. The rope/cable should run from a known point in the working sections to a place of safety (i.e. a refuge bay or cache of long duration SCSRs),
- that an effective early warning method be developed and installed to timeously warn underground personnel against impending danger,
- that methods and means be introduced to assist mine personnel in orientating themselves in working sections, and following designated escape routes,
- that, owing to complications introduced by low visibility, back-up facilities be placed closer to the workings. Previous guidelines in this regard should thus be revised and the installation of intermediate or less formal refuge bays should be considered to reduce travelling distances,
- that travelling roads be regarded as the preferred escape routes instead of conveyor belt roads,
- that personnel be trained to use designated escape routes, .i.e. workers should familiarise themselves fully with the escape route by walking the route,
- that the provision of directional guidance to refuge bay doors is imperative, and finally,
- that the possibility of equipping all workers with goggles to provide eye protection against airborne irritants be investigated."

In order to provide guidance, a continuous line of rope or cable should run between predetermined points and places of safety i.e. refuge bays, mine exits etc. This line should be equipped so that the direction of the place of safety can be determined by feel.

Barricades suspended across the full width of roadways except travelling ways in such a manner as to prevent persons from passing a place of safety or diverting from the route to a place of safety can be determined by feel.

2.5 Refuge bays

The mine should be equipped so that every person working or travelling underground may reach a refuge bay or other place of safety within the duration of his SCSR even when used under adverse conditions (i.e. zero visibility). This therefore includes not only production sections but also workshops, stores and all personnel (including contractors) working or travelling outbye of the sections.

It is suggested that this distance be experimentally determined for each mine by selecting a number of test subjects from a spread of the worker population (including some new employees) and conducting trials with blindfolded subjects and ascertain how far they could travel (including time required to locate the life line) within a percentage (60-70 percent) of the known duration of the particular SCSR in use on the mine. This figure would then give a good indication for maximum refuge bay spacing on a particular mine.
It must be borne in mind that these escapes will be made in the aftermath of an explosion or during a fire and basing the spacing on anything approaching normal conditions would not be best practice.

SIMRAC Report COL 115 – "Assessment of Refuge Bay Designs in Collieries"
discusses the characteristics of explosions, design criteria for bulkheads and makes appropriate recommendations.

One of the problems encountered is, that due to rapid face advance, keeping up with the building of formal refuge bays can present problems. Consideration can be given to the construction of either less formal refuge bays or transportable refuge bays equipped with oxygen generators that are capable of surviving an explosion.

The CoP for Escape and Rescue should clearly specify the siting, construction requirements and equipping of refuge bays of all types and the procedures to be followed in an emergency.

Formal colliery refuge bays should be of adequate size to cater for the anticipated number of persons expected to occupy it, plus a 20 per cent factor of safety and the size should be based on 1,0 m^2 per person. Walls should be capable of withstanding a pressure differential of 140 kPa. Steel, self-closing airlock doors and suitable bleeder pipe must be installed. In addition, they are required to comply with Regulation 24.20.2.2.

Colliery refuge bays can either be ventilated by a borehole from surface or by oxygen generators or cylinders of compressed air, whichever is appropriate in the prevailing circumstances.

It is essential that the condition and equipment of all refuge bays be checked and logged regularly by a person, who is accountable, appointed in writing.

All refuge bays or places of safety should have suitable instructions posted up. These should be in appropriate languages and pictorially, to cater for illiterates.

Where refuge bays are ventilated from surface the mine should have two or more systems to enable fresh air to be pumped down the borehole and have arrangements with local mines to draw on additional units that can be immediately connected on arrival. i.e. power supply, connections etc. are compatible.

Finding the borehole sites, particularly at night in an emergency, can be problematic. Therefore, it is recommended that the borehole locations are not only clear marked on plans but, are clearly signposted on surface, along with the routes to them.

3 Training

In order to ensure that the escape and rescue systems that have been put into place on the mine are effective in the event of a life-threatening incident, it is essential that all personnel involved are properly trained in evacuation and refuge bay procedures.

The mining industry is aware of numerous instances where persons have either not received timeous warning, have not located refuge bays, or have passed them by in an attempt to escape, often with fatal results. Therefore, it is essential that adequate initial and refresher training programmes be in place on the mine.

3.1 Receiving adequate warning:

The distribution of CO warning and measuring devices should be such that *all* persons in the area can be warned to evacuate.

Some gas detection instruments are sophisticated, multi-functional devices that give a great deal of information. However, numerous instances have been encountered where considerable (and dangerous) confusion has been observed over the interpretation of the information they provide.

Instruments that provide numerical readouts can lead to confusion. Serious consideration should be given to CO warning devices *for use by the "general population"* be of the "go - no go" type. i.e. One red light and a buzzer which is set for 100 ppm CO would give the alert to evacuate. A second light and other buzzer set at 400 ppm would give the alert to don the SCSR.

3.2 Self contained self rescuers

Once the issue of adequate and timeous warning is addressed, training in the use of the SCSR must be carefully considered. Being a device, which is hopefully never actually used, persons tend to forget about it.

The training programme should be developed in conjunction with the supplier utilising the appropriate training aids, including training sets, breathing simulators, videos and posters.

This training is required by statute to be repeated six monthly, and when a person has been absent for more than 30 days it should be repeated. It must also be part of the regular on the job safety training.

3.3 Locating the refuge bay or place of safety

Having to escape in adverse conditions (i.e. zero visibility) can cause considerable psychological trauma and panic. It is therefore suggested that as part of the initial and refresher training all workers be put through a "*stressful*" blindfolded simulated escape, using the lifeline to find their way to a refuge bay. Once in the refuge bay they are given appropriate instruction on refuge bay procedures.

All members of the wok force must not only know exactly what to do in the case of an emergency but have practised it underground.

3.4 Escape drills

Regular escape drills must be carried out and these must be logged, with appropriate comments by the supervisors. Persons who require further training must be given it.

The effectiveness of the training and the retention of the information received during the training must be monitored. This is best done by rigorous, independent audits not only of the actual training programme in the Training Centres and the routine safety training, but also of the workforce itself in the actual work place.

4 Disaster management

In any emergency situation it is essential that those involved in the management as well as rescue and recovery operations know beforehand the Emergency Response Strategy and Management Plan, what facilities they have available and where assistance can be obtained.

Any event that could result in an emergency or indeed any abnormal situation that could have an adverse effect of the operations of the mine should have a formal, approved response procedure available.

These procedures should be familiar to members of the mine's management team and they should be readily available for consultation during any situation.

These procedures should be subject to regular review. It is suggested this be done annually or when any change in circumstances necessitates a review. The various procedures should be in the charge of the appropriate member of the management team, who should be accountable for ensuring the review. Any review (even if there are no changes) must be dated and signed by the responsible person(s).

4.1 Control rooms and associated facilities

When any emergency is to be managed, proper facilities and equipment are essential. In the mining situation it is prudent that the location of any control be pre-arranged and all relevant persons are aware of how to establish contact with it.

Control rooms should have adequate communications facilities, working space and storage space for the necessary procedures and plans.

Dedicated control rooms are the preferred option. However, existing facilities can be utilised with some forethought. (i.e. installation of extra telephone lines, additional filing and plan holding facilities). There is often a need for the immediate availability of stationery and a sealed pre-packed box of stationery is useful.

The immediate availability of call-out lists giving up to date office and residential/cellular telephone numbers is a requirement and this should be prominently displayed. Normal and after-hours contact numbers for emergency services (including Mines Rescue Services) and adjacent mines should also be available. These call out lists should be comprehensive and be such that even a miner can be contacted after hours in the event that either his services or his intimate local knowledge of the working place is required.

There should be and adequate selection of materials and equipment immediately available to deal with any emergency situation. The Mines Rescue Services are in a position to provide advice on what should be held.

4.2 Situation management and rescue operations

When any emergency arises, it is essential that those involved are fully aware of their duties and responsibilities. This requirement extends to all levels of personnel and should be part of the initial training and of any training or information transfer, that takes place on promotion.

The general duties of each department in an emergency should be formally laid out in a procedure.

Initially, the most senior, technically qualified person takes charge and issues such immediate instructions as deemed necessary to safeguard life and property until formal control can be established.

In general, the head, or in his absence his deputy, of the appropriate department is contacted, briefly appraised of the situation and then contacts the appropriate subordinates putting into action the required response from his department.

It is essential that all instructions given and information received be clearly and fully recorded in a situation logbook giving the date and time on a 24 hour clock system. It is always best to have a technically competent person acting as scribe under such circumstances.

Before any rescue team is sent into a mine following a fire or explosion, the possibility of an explosion or secondary explosion must be considered and assessed as far as is reasonably practical. This should be recorded in the log of control room actions.

Such decisions should be based on:

- State of the ventilation.
- State of the atmosphere in the mine (in or near explosive range).
- Source of ignition. Great care should be exercised if spontaneous combustion is suspected.
- Presence of flammable gas due to walls of sealed areas being damaged.
- Likelihood of survivors.

5 Disaster recovery

Once the emergency has passed, control room involvement can either be reduced or terminated and work commenced to recover from the situation and restore operations to normal.

All instructions, including sequence of actions, should be formally documented.
Appropriate supervision must be put in place to ensure the instructions are carried out in a correct and safe manner.

6 Media relations

Any emergency, particularly those that involve multiple fatalities, damage to third parties, cause environmental pollution or are likely to be of public interest are liable to warrant the attention of the media.

Handling the media can be a sensitive matter. An early, open and technically accurate interview or statement with regular updates and according the media reasonable facilities can result in fair and sympathetic reporting under what can be adverse circumstances.

It is well known that some media reporting can be emotive, speculative and/or inaccurate. This fact should be kept in mind when dealing with the media.

All statements issued by the mine to the media should be officially issued by the Owners, Manager or designated media liaison officer. No off-the-cuff interviews and ad-hoc comments should be given by other officials. They should refer any media queries to the Manager or media liaison officer.

7 Quality assurance

The mining industry (and other industries) is full of cases where excellent plans, procedures and standards have been drawn up but are have either not been properly implemented, or reviewed and updated. Otherwise they have just simply fallen by the wayside to a greater or lesser extent. This is particularly true with procedures that are not in daily use, or which are perceived as a "nuisance" to carry out without immediate tangible benefit.

The only way to ensure that best practices are used in any organisation is to implement a rigorous system of quality assurance.

This requires a *formalised* monitoring programme within the organisation with clearly laid down responsibilities and backed up by an independent audit applying the benchmark of industry best practices.

DOCUMENT 3

A Minerals and Mining Policy for South Africa

Green Paper for public discussion

February 1998

Invitation for Public Comments

The public is invited to respond to the Green Paper on the Mineral Policy of South Africa. Written responses should reach the Department of Minerals and Energy at the address below not later than 31 March 1998.

Written comments on the Green Paper should be sent to:

The Director
Minerals Bureau
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Braamfontein
2017

Attention: Ms TD Gcabashe

Telefax: (011) 403-2061
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Introduction

South Africa's mining industry is supported by an extensive and diversified resource base, and has since its inception been a cornerstone of South Africa's economy. The changes which have come about in our country make it necessary to prepare the industry for the challenges which are facing all South Africans as we approach the twenty-first century.

The review process has taken account of the problems and opportunities confronting the mining industry against the backdrop of changes in the country's policy and institutional environment. In particular, the passage to the Mine Health and Safety Act of 1996 will have far reaching impacts on the industry in the areas of health and safety and human resource development. Changes in labour legislation and the introduction of employment equity legislation, as well as the reform of the environmental regulatory system, create a dynamic context for this policy review. Beyond our borders increasing competition, both in commodity markets and for investment, from mineral-rich countries that have liberalised their economic and political systems to attract investment are significant influences on the policy reform process.

The policy review process has had to take account of current problems and opportunities facing the mining industry. The gold mining sector particularly, is having to re-examine its production techniques in the light of a static gold price, deep levels of working and higher operating costs. Undoubtedly some of the older mines are reaching the end of their lives, leading to job losses and the other attendant negative effects of downscaling, but these problems are being tackled energetically within the sector, through restructuring of mining groups, technological advances and innovative methods of improving productivity. Apart from gold mining, there are many other minerals being produced, for some of which South Africa is the leading producer and holder of reserves. The Green Paper also has a chapter on small-scale mining which is intended to encourage the small and medium sized operator, to the benefit of employment and the overall economy. Future mineral policy has to take account of the international nature of the mining industry in order to ensure the continuing prosperity of our own mines.

In September 1995 the Mineral Policy Process Steering Committee was formed consisting of representatives from both the executive and legislative branches of Government, as well as organised business and organised labour. The mandate given to the Steering Committee was to conduct an extensive consultative process to canvass stakeholder opinion for the preparation of a new minerals and mining policy for South Africa. In November 1995 a *Discussion Document on Minerals and Mining Policy for South Africa* was published and extensive written comments were received. Four hundred people attended public mineral policy workshops held in March 1996, at which a wide range of issues were debated. Bilateral meetings were held with *inter alia* provincial governments, ministries, departments, investment analysts, foreign-owned mining companies and environmental interest groups. In addition written submissions were received from several interested parties during the consultative process. Details of these consultations are recorded in an appendix. The end result of this, the most comprehensive consultative process yet conducted for a review of a minerals and mining policy in South Africa, was a document containing proposals that have been drafted after careful consideration of a very broad range of views. The submission of the document to the Minister of Minerals and Energy concluded the task of the Steering Committee.

The Minister requested the Department of Minerals and Energy to consider certain adjustments to the document in line with his budget speech in the National Assembly on 21 May 1997. The views of stakeholders, such as small-scale miners, environmental groupings and communities, who felt that they were not properly consulted by the Steering Committee, as well as the outcomes of other policy processes (e.g. CONNEP) were also considered in the final editing of the document. The document was then ratified and signed by the Minister of Minerals and Energy as a Green Paper on Minerals and Mining Policy for South Africa.

The Green Paper is organised into six main themes covering the issues which have been identified by the Steering Committee in the process of consultation discussed above. These are:

- Business Climate and Mineral Development, which looks at the continuation of policy conducive to investment and includes a section on Mineral Rights and Prospecting Information which proposes changes to the system of access to, and mobility of, mineral rights;
- Participation in Ownership and Management, which examines racial and other imbalances in the industry;
- People Issues, which looks at health and safety, housing needs, migrant labour, industrial relations and downscaling;
- Environmental Management;
- Regional co-operation; and
- Governance.

Each chapter and subchapter contains a general background to the particular issue, a statement of intent (policy objective), the views of the different stakeholders and, finally, the policy statements by Government.

Policy making occurs in a dynamic setting, and minerals and mining policy, which is necessarily broad in its scope, needs to be co-ordinated with other policies which properly fall within the remit of other forums. Reference is therefore made in the document to matters that need to be considered by other policy forums, such as the Commission of Inquiry into Certain Aspects of the Tax Structure of South Africa.

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Chapter One:
BUSINESS CLIMATE AND MINERAL DEVELOPMENT

This chapter covers seven topics relevant to the climate for mining business and mineral development.

Section 1.1 stresses the importance of a stable macro environment for economic growth in which measures that encourage investment in mining, as in other industries, are adopted.

Section 1.2 is concerned with fiscal policy as an integral part of mining and minerals policy. Several aspects of exploration and mining which have a major bearing on fiscal policy are raised together with policy proposals that are prerequisites for minerals development. The Commission of Inquiry into Certain Aspects of the Tax Structure of South Africa (Katz Commission) is currently considering mining taxation and the taxation of mineral rights. In due course the Commission's findings should be considered in conjunction with the broad objectives of minerals and mining policy. The topics of taxation of mineral rights and allocations from national revenue collection to provinces in which mining takes place are raised in section 1.3 and in chapter 6, respectively.

Section 1.3 deals with mineral rights and prospecting information. The nature, scope and content of rights to prospect and mine are central to any policy on minerals and mining. It has been contended that the system of mining and mineral rights currently in place in South Africa has frustrated new investment. Equally, however, others have argued that the legislative framework has helped materially in the exploration and mining of South Africa's unique mineral deposits. In reaching policy conclusions Government must weigh these and other contending views. In order to improve current arrangements, Government will seek changes and adjustments that are conducive to increased minerals investment and address past racial inequity without disturbing investor confidence in the mining industry in South Africa. Several new proposals are put forward.

Section 1.4 focuses on small-scale mining and puts forward a number of policy proposals directed at encouraging and facilitating the development of the small-scale exploration and mining sectors.

Section 1.5 looks at mineral beneficiation in broad outline. Several policies aimed at the development of South Africa's mineral wealth where this is economically justifiable are proposed.

Section 1.6 takes the view that in the area of mineral marketing, policy should endorse market principles and provide for Government to play a supportive role.

The last section focuses on research and development infrastructure conducive to the optimal development of the country's resources. A number of policies directed at stimulating such development and ensuring the continuing competitiveness of the minerals industry are proposed.

1.1 Investment and Regulatory Climate

1.1.1 Background

i. The South African mining industry, one of the country's few world-class industries, has the capacity to continue to generate wealth and employment opportunities on a large scale.
ii. Mining is an international business and South Africa has to compete against developed and developing countries to attract both foreign and local investment. Many mining projects in South Africa have tended to be unusually large and long term, requiring massive capital and entailing a high degree of risk.
iii. South Africa has an exceptional minerals endowment, and in several major commodities has the potential to supply far more than the world markets can consume.
iv. As articulated in its macroeconomic strategy, Government has committed itself to a continuing process of economic

liberalisation, thus strengthening the competitive capacity of the economy, fiscal and tariff reform and bureaucratic deregulation. These are essential steps towards enhancing the country's competitiveness, attracting foreign direct and portfolio investment and creating a climate conducive to business expansion. The mining industry among others will benefit in the long term from these developments.

v. By its very nature the mining industry has the potential to endanger human health and safety as well as the physical environment. It is the responsibility of Government to establish a regulatory framework that minimises such dangers without imposing excessive cost burdens on the industry and thereby jeopardising its economic viability.

1.1.2 Intent

Government will create a stable macro-environment that supports economic growth and in which business, subject to appropriate regulation, can operate profitably, be internationally competitive and satisfy their shareholders' and employees' expectations. In this way Government will encourage investment in mining as in other industries.

In addition, Government will facilitate access to business opportunities and resources to those previously excluded, including helping equip such individuals/groups with the necessary skills to enable them to compete effectively in the market-place.

1.1.3 Policy Requirements

1.1.3.1 Views of the investment community and mining companies

i. The distinctive characteristics of the mining industry need to be recognised in the formulation of the policy and regulatory framework. The framework must be consistent and stable so that investors can be confident in their financing decisions and the industry can be confident about its continuing ability to do business profitably.
ii. Investors place a high premium on macro-economic, political and social stability, as well as smoothly functioning labour relations.
iii. Foreign investors need the freedom to repatriate profits and capital.
iv. South African-based mining companies wish to see a speeding-up in the comprehensive dismantling of foreign exchange controls.
v. Investors need security that they will be allowed to exercise their rights to exploit minerals, subject to statutory requirements.
vi. Non-confidential and publicly available information about the minerals sector needs to be well organised so that it is readily accessible to investors.
vii. New investors need opportunities for access to mineral rights.

viii. The cornerstones of any policy to promote investment must be market principles and economic efficiency.
ix. The nature of international mineral markets and of South Africa's mineral resources must be taken into consideration when promoting investment, including the effect of increased supplies on prices.

1.1.3.2 Other views

i. Equitable access to all natural resources is required, based on economic efficiency and sustainability.
ii. The creation of wealth and employment is required for the economic empowerment of communities, both directly and through the multiplier effect. This is especially relevant in the underdeveloped regions of the country.
iii. Investment incentives and promotional activities should be cost-effective and should not lead to inequitable demands on the fiscus.

1.1.4 Policy Proposals

i) Government will seek to create a macro and regulatory environment conducive to economic growth and development, in which the mining industry can make effective use of its human and capital resources.

ii) Through the new Labour Relations Act and the specific industry-level and workplace structures it creates, Government will facilitate improved industrial relations in the industry.

iii) Government will seek to ensure, within the constraints of its available resources, the efficient provision and functioning of the physical, social and institutional infrastructure necessary for the competitiveness of the mining industry.

iv) Government will ensure the effective organisation and accessibility of public information about the minerals sector.

v) Government will aim to lower barriers to entry to prospective new investors in the industry.

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1.2 Taxation

1.2.1 Background

1.2.1.1 The current system of mining tax

i. The taxation of mining activities follows the normal rules of taxation, subject to the following particular features:

a) Income

A mining company may derive income from mining operations and non-mining operations. Different rules and tax rates are applied according to the nature of such income. Differences also apply according to whether the mining income is derived from gold or other operations.

b) Deduction of expenditure

A mining company incurs a wide range of expenditure. Some of this is in the nature of current expenditure (deductible in terms of the general deduction formula), and some in the nature of capital expenditure. The capital expenditure provisions of the Income Tax Act provide for the immediate deduction of capital expenditure and of expenditure on prospecting and incidental operations. Capital expenditure includes expenditure on shaft sinking, mine equipment, development, general administration and management. Some assets such as housing for residential accommodation, motor vehicles for private use of employees, and some railway lines and pipelines qualify only for a partial annual redemption.

c) Ring-fencing

The Income Tax Act applies a ring-fence to the taxable income of a mine, by restricting the deduction of its capital expenditure to the taxable income from mining on that mine. In certain circumstances the ring-fence may be breached by up to 25% of taxable income to allow a company to apply a portion of its expenditure on one mine against the taxable income of another of its mines.

d) Capital allowance

To encourage high capital investment during times of inflation, the Income Tax Act provides for a capital allowance, calculated as a percentage per annum of total expenditure, which is transformed into a deduction against current capital expenditure.

e) Environmental funds

Mining companies are required by law to make financial provision for mining-related environmental rehabilitation. If in the form of a trust fund, the Income Tax Act permits the deduction of this provision from income, and exempts from tax the receipts and accruals of registered environmental funds established to hold these provisions.

f) Tax rate and formula tax

Non-mining income, as well as mining income not derived from gold mining is taxed at the flat company rate. Income from gold mining is taxed on a formula basis. The effect of the formula is that gold mines which are marginally profitable pay tax at a lower rate than the normal company rate, or no tax at all, and more profitable gold mines pay tax at a rate greater than the normal company rate. The intention of this is to encourage the mining of marginal orebodies, while retaining an overall tax rate for the gold industry at approximately the same rate as the standard company rate. The formula tax, therefore, has the effect that a gold mine can continue to operate at marginal profit levels without paying tax until it regains profitability sufficient to attract tax. In this way it preserves employment in an industry which has a large number of employees and is prone to fluctuations in profitability.

g) Royalties

For purposes of this chapter, royalties are not regarded as a tax and are discussed in section 1.3.

h) Other

No severance tax is imposed. Mining companies are liable, in certain circumstances, to the secondary tax on companies. Indirect taxes paid by mining companies include value-added tax, regional services levies, transfer duties, customs and excise duties and donations tax. (In the case of value-added tax a mining company does not pay the tax on its export sales, since all exports are exempt, and the mine is entitled to a refund in respect of all input taxes paid by it.)

1.2.1.2 Aspects of exploration and mining which have a bearing on mining tax

i. Any mining taxation system needs to recognise the following aspects:
    a. The risk to reward ratio in exploration is high, and mining itself is attended by a high degree of geological, project and market risks.
    b. Particularly in big-scale and deep-level operations large amounts of capital are required. This capital is at high risk over long periods.
    c. Mining companies are usually required to provide their own infrastructures because of the remote location of mineral deposits.
    d. Mining involves the realisation of a wasting asset and the mine has little or no residual value. Continuing investment is therefore necessary in exploration, the acquisition of rights to mine and the development of new mines. All these activities form an essential part of the mining business cycle.
    e. Taxes that increase mining costs have the effect of increasing the cut-off grade of ore, thus reducing the life of a mine and sterilising mineral assets. It has therefore long been recognised that, in principle, mines should be taxed on profit and not in a manner which increases costs.
    f. Legitimate expenses should be treated in an appropriate way, the efficient use of resources should be encouraged and not retarded, and the system should not be subject to frequent change, change at short notice or change with retrospective effect.
    g. In view of international competition for investment funds,

the tax system should be designed to assist in attracting and retaining investment in South Africa.

h. In several countries a policy that the State should be compensated for the finite natural resources which are mined finds expression in the imposition of a severance tax. According to the Margo Commission a severance tax imposed on profits becomes a discriminatory surcharge on income tax. If imposed on revenue, or on physical production, it raises costs at the margin and renders unpayable bodies of ore that, but for the tax, would be payable. In addition a severance tax may also be unfairly discriminatory in penalising the primary winning of minerals as opposed to their subsequent beneficiation and utilisation in manufacturing.

1.2.2 Intent

Government will maintain and promote a stable legal and fiscal climate that does not inhibit the mining industry from making the fullest possible contribution to the national economy.

1.2.3 Policy Requirements

1.2.3.1 Views of the investment community and mining companies

i. There must be a consistent and stable fiscal regime that compares favourably with those in other jurisdictions.
ii. The tax system should be such as to allow for attractive returns on capital.
iii. The tax system should recognise, through appropriate measures, the risks inherent in mining, such as high capital commitment, long lead times, geological uncertainty and cyclical and volatile markets.
iv. Mineral beneficiation projects share many of the risks referred to above.
v. Mines should be taxed on profits and not in a way which increases costs.
vi. The total tax burden is highly relevant to investment decisions so the levels and structures of national, provincial and local taxes, levies and imposts should be assessed in their entirety. The industry should be consulted when decisions regarding mining taxation are to be made.
vii. The tax system should not discourage, in particular through ring-fencing, the use of the financial strengths of an existing company to invest in the establishment of new mines.
viii. Severance taxes should not be imposed.

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1.2.3.2 Other views

i. The mineral industry should make its rightful contribution to tax revenues, both through taxes and royalties.

ii. The tax system should encourage the adding of value to raw materials.
iii. Levies and taxes should be used to fund environmental rehabilitation of land affected by past and current mining activities.
iv. Inter-sectoral equity in terms of taxation should be achieved.
v. Consideration should be given to using tax measures to improve access to mineral rights.
vi. The tax system should promote the optimal utilisation of South Africa's mineral resources.
vii. The tax system should be used to empower the provinces to influence the economic development process and to deal with the effects of downscaling.

1.2.4 Policy Proposals

i. In developing mining tax policy, Government is committed to ensuring that the tax regime will be consistent and stable and that the aggregate rate of tax will be internationally competitive.
ii. Government will seek, wherever possible, to minimise taxes which increase the costs of mining.
iii. Government is committed to ensuring that the tax system does not inhibit mining but encourages the efficient use of resources.
iv. The Katz Commission is investigating mining tax in South Africa. The Commission's recommendations will need to be considered in conjunction with the policy options set out here. It is understood that the Commission will be considering a number of tax issues, for example:
    a. redemption of capital expenditure in mining;
    b. capital allowances for gold mining;
    c. ring-fencing;
    d. tax deductions for exploration;
    e. a tax on mineral rights; and
    f. the extension of the gold-mining formula taxation to other types of mining.

1.3 Mineral Rights and Prospecting Information

1.3.1 Background

1.3.1.1 Nature and content of mineral rights

i) The South African system of mineral rights has developed over many years to its present state under a dual system in which some mineral rights are owned by the State and some by private holders. The State controls the exercise of prospecting and mining rights under the administrative system of prospecting permits and mining authorisations referred to below.

ii) Under common law, ownership of the land includes ownership of the minerals in the land. The law developed in such a way that the right to minerals in respect of land can be separated from the title to the land, for example upon original grant of the land or by subsequent transactions. The owner of land from which mineral rights have not been separated may separate the mineral rights from the land ownership by ceding them to another person or by reserving them to himself or herself. The mineral rights are then held under separate title which may include all the minerals in the land concerned or only a particular mineral or minerals.

iii) Mineral rights constitute rights in land. They are officially registered by the State, and are a form of property protected under the Constitution.

iv) Mineral rights are tradeable. They have been and continue to be the subject of considerable financial investment that has resulted in the acquisition and registration of rights by prospectors and miners over relevant areas of interest.

v) Mineral rights represent a parcel of rights including the rights to prospect and mine together with ancillary rights to do what is reasonably necessary in order to effectively carry on prospecting or mining operations. The holder of mineral rights may grant subordinate rights to prospect under a prospecting contract or grant subordinate rights to mine under a mineral lease or may sell or otherwise dispose of the rights.

vi) The mineral rights owner is compensated by the exploiter of the minerals for the depletion of the non-renewable resource through the payment of royalties. It is generally accepted that in principle royalties are charged on production or revenue.

1.3.1.2 Ownership of mineral rights

i. The two main categories of owners of mineral rights are the State and private holders. Unfortunately, the current deeds registry system does not provide reliable overall figures indicating what percentage of the mineral rights is owned by each of these categories of holders. Statistics kept by the Department of Minerals and Energy since 1993 indicate that with the exclusion of the coastal zone and sea areas, the mineral rights in respect of which prospecting permits and mining authorisations have been issued are divided in the proportion 1/3 state-owned and 2/3 privately owned. This does not necessarily imply that for the country as a whole, including the coastal zone and sea areas, mineral rights are held in these proportions, but illustrates that the private sector is a substantial holder of mineral rights. A distinguishing feature of the South African mining industry at present is that almost all privately-owned mineral rights are in white hands.
ii. In the former TBVC states and self-governing territories mineral rights were largely owned by those states and territories but, for the purposes of prospecting and mining legislation, administered as if they were privately owned. It has been estimated that mineral rights in respect of some 19 million hectares, which represent 15% of the land area of the Republic,

fall into this category, including mineral rights held by Government in trust for specific tribes and communities. This category also includes those mineral rights which vest in the Lebowa Minerals Trust under the Lebowa Minerals Trust Act, 1987, and the Ngonyama Trust under the Kwa-Zulu Ngonyama Trust Act, 1994. In terms of the present Constitution, mineral rights in this category vest in the State except for those held by the abovementioned two trusts as well as mineral rights held in trust for specific tribes.

iii. The State is the owner of mineral rights in various areas of surveyed and unsurveyed State land as well as in privately-owned land where mineral rights have specifically been reserved to the State. Under prior legislation the latter class of land was known as 'alienated State land' in respect of which prospecting rights together with the exclusive right to obtain mining rights were vested in the landowners or their nominees. According to section 43 of the Minerals Act, such rights were replaced with similar rights for a period of only five years which ended on 31_December 1996.

iv. Mineral rights in certain rural areas, situated mainly in Namaqualand and in the Northern Cape, are regarded as state-owned for the purposes of the minerals legislation. However, management boards in those areas exercised through the years extensive authority in respect of the granting of prospecting and mining rights.

v. Provision has been made in the Constitution read with the Restitution of Land Rights Act, for relief to persons or communities who were dispossessed of rights in land under any racially discriminatory law after 19 June 1913. Mineral rights are rights in land and can therefore be subject to the Act.

vi. There is an active market and continual movement in mineral rights, some 6 000 mineral cessions and prospecting contracts having been registered in deeds offices in South Africa for the five year period from 1991 to 1996.

1.3.1.3 Provisions for intervention by the State

In addition to the modes of acquisition of mineral rights referred to in paragraph 1.3.1.1 iv) above, the State can intervene under section 17 of the Minerals Act to grant prospecting rights in circumstances where an intending prospector cannot trace the holder of the mineral rights or where an heir has not taken cession of the mineral rights in an estate. According to section 24 of the Minerals Act, mineral rights and other rights in land may be expropriated in the public interest against compensation payable by the person requesting expropriation. It is therefore possible to expropriate the right to prospect and the right to mine. Under the current law, the State may, by virtue of section 18 of the Minerals Act, conduct an investigation on any land to establish the presence, nature and extent of minerals in or on that land, provided that such an investigation is in the national interest.

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1.3.1.4 Other jurisdictions

i. South Africa and the USA are two of the few major mining countries which have a dual system of public and private ownership of mineral rights. In most other countries the right to minerals is vested in the State. However, in some countries, of which Chile and Australia are good examples, the state system is such as to allow a mining company *de facto* permanent title to such rights.
ii. In jurisdictions where mineral rights are publicly owned, a system of licensing is usually applied which provides security of tenure sufficient to attract exploration and mining. Many countries, notably in South America but increasingly elsewhere, which employ licensing systems for publicly-owned mineral rights, have successfully attracted large and continuing investment in exploration and mining.

1.3.1.5 The exercise of prospecting and mining rights in South Africa

i. In South Africa, the mineral right owner is not permitted to prospect or mine for minerals without having obtained a prospecting permit or mining authorisation from the State. These licences are not transferable. They are aimed at controlling prospecting and mining, having regard to considerations of health and safety, environmental rehabilitation and responsible extraction of the ore. Conversely, a prospecting permit or mining authorisation cannot be granted unless the applicant is the holder of the relevant mineral right or has acquired the holder's consent to prospect or mine.
ii. Reconnaissance work can and does take place without the necessity to hold a permit, provided the work does not fall within the definition of 'prospecting' in the Minerals Act.

1.3.1.6 Records of prospecting work

i. According to section 19 of the Minerals Act, the holder of any prospecting permit or mining authorisation is obliged to furnish certain prospecting information to the State within one year after completing the digging of any excavation or drilling a borehole for the purpose of prospecting. The information must be kept confidential by the State. When 15 years have elapsed from the date of the completion of the excavation or borehole concerned, the State may disclose the information unless any person with a pecuniary interest in the excavation or borehole satisfies the State that his or her interest will be prejudiced by such disclosure.
ii. In most other jurisdictions confidentiality against disclosure to third parties of basic prospecting information furnished to the State is afforded during the currency of the prospecting licence or for very short periods. In such jurisdictions, where public ownership of mineral rights prevails, the policy is directed at assembling a public record of exploration work as a resource for future exploration.

1.3.2 Intent

Government will:

i) promote exploration and investment leading to increased mining output and employment;

ii) ensure security of tenure of mining rights;

iii) prevent hoarding or sterilisation of mineral rights;

iv) address past racial inequities by assisting those previously excluded from participating in the mining industry to gain access to mineral rights;

v) recognise the responsibility of the State as custodian of the nation's mineral rights; and

vi) take reasonable legislative and other measures, to foster conditions conducive to mining which will enable entrepreneurs to gain access to mineral rights on an equitable basis.

1.3.3 The Present System: Views For and Against

Many differing views have been expressed in support of or against the current arrangements in respect of mineral rights and prospecting information.

1.3.3.1 Private ownership

i. Proponents of private ownership maintain that:
   a. It has been and remains ideally suited to effective utilisation of South Africa's distinctive ore bodies, for example, by providing the absolute security of tenure necessary in the development of very deep gold mining along the West Wits line. The capacity to retain mineral rights securely for the development of new mining ventures when these become possible is a positive feature of private ownership.
   b. Holding of mineral rights is a critical parameter in the valuation of a mining company by international investors. The company is valued according to its future potential ('blue sky') which depends on an ongoing flow of new projects derived from such mineral holdings.
   c. Private ownership of mineral rights based in the law of property is preferable to a pure licensing system of rights based in administrative law and involving administrative discretion. Private ownership affords the absolute long-term security of tenure that attracts investment in exploration, mining and marketing.
   d. South Africa has the ability to produce at a level far exceeding the world's ability to consume several commodities such as manganese, chrome, platinum and vanadium. Mineral rights in such commodities are held as part of long-term mining plans. Owners have a record of

having expanded production in line with growth in demand and have also invested substantial funds in new product development and other forms of promotion to foster market growth.

e. Private ownership is consistent with a market economy and with an international trend towards reducing the direct role of Government in the mining industry.
f. Private ownership encourages trade in and utilisation of mineral rights, as is evident from the figures referred to in paragraph 1.3.1.2 above.

ii. Critics of private ownership of mineral rights argue that:
   a. Minerals are part of the nation's endowment so that the State is the rightful custodian of this endowment.
   b. South Africa (along with the USA) is out of step with other major mining countries, where public ownership of mineral rights has led to successful exploration and mining industries.
   c. Private ownership of mineral rights suppresses exploration activity as well as the opportunity for alternative views to be taken of the economics of mining an unexploited ore body.
   d. It allows hoarding of mineral rights. As such, the system is a barrier to entry against potential investors.
   e. Complex and fragmented mineral right holdings and the multiplicity of owners in South Africa militate against new investment by prospective new entrants who encounter difficulty and cost in identifying holders of mineral rights and obtaining mineral rights.
   f. The system is inaccessible to small-scale miners, and inhibits the development of a vibrant junior mining sector.
   g. Private ownership of mineral rights limits equal and equitable access to mineral rights and resources.

1.3.3.2 State ownership

i) Those in support of the transfer of privately-held mineral rights to the State contend that:

a. Transfer of mineral rights to the State will release mineral terrains for new entrants, which will stimulate private sector activity.
b. State control of mineral rights will remove difficulties in cost and delays surrounding fragmented mineral right holdings.
c. A system of state-owned mineral rights would enable the State to enforce the submission and release of exploration information, thereby avoiding duplication of exploration activities.
d. State ownership of mineral rights is more prevalent in the world than is private ownership of mineral rights.
e. State ownership will prevent the hoarding of mineral rights and allow equal and equitable access to potential investors, in particular small-scale miners.

ii) Contentions raised against a transfer of mineral rights to the State are that:

a. Transfer of mineral rights to the State will require the payment of compensation, which would be an inappropriate use of the State's limited financial resources.
b. The blanket transfer of mineral rights to the State could easily lead to administrative difficulties in a system not geared to the management of mineral rights, extensive delays and hence a loss of investor confidence that could seriously damage the South African mining industry.
c. There is no indication that the transfer of mineral rights to the State will automatically result in more successful exploration and mining. It is argued that in South Africa there is evidence to the contrary in that state ownership of mineral rights has made these rights subject to policies that have impeded rather than promoted mineral development. As indicated above, it has been estimated that two-thirds of the mineral rights in respect of which prospecting and mining activities are conducted are privately held. Management of deposits that will be brought to account in the future requires a long-term perspective attuned to changes in technology and markets that is more likely to be found in the private sector.
d. State ownership based in a system of administrative law offers less security than a system of private ownership based in the law of property, and is susceptible to inefficiency and corruption.
e. A bias towards state ownership would run counter to the Government's philosophy and policy on competition and privatisation.
f. Prospecting information and mineral rights are separate forms of property. Ownership of the latter does not automatically confer title to the former.

1.3.3.3 Disclosure of prospecting information

In relation to prospecting information there are broadly two contending views. On the one hand, it is argued that more data on prospecting results should be made publicly available as a resource for future exploration efforts by new prospectors and prospectors with new techniques. Against this it is held that prospecting data are the product of effort and investment by prospecting companies, the data constitute property that can be bought and sold and an incentive should be provided for the prospecting effort to be undertaken by protecting the confidentiality of the data for a reasonable period. As a further complication, contentions in support of the public release of prospecting data after fixed periods ignore the nature of prospecting programmes that do not have a readily determinable point of completion.

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1.3.4 Tax on Mineral Rights

One view is that a tax should be imposed on privately held mineral rights to open access to such rights. Such a tax would not be payable by operating mines or where the retention of mineral rights is part of a long-term mining strategy that is in the national interest, or where there is active exploration taking place. If the owner of the mineral rights is unable or unwilling to pay a mineral rights tax, the rights may either be sold to a willing purchaser or at no cost to the owner be transferred to the State.

i. Opponents of such a tax reject the view that the rights would be better utilised if transferred to the State. They have also contended that it would be contrary to the Constitution to use a tax to induce taxpayers to surrender assets to the State without payment for these assets. In addition to questions about the constitutionality of such a tax, and whether it will achieve its objective, opponents of such a tax contend that there are practical difficulties in applying such a tax; for example, how could this be done equitably across a range of mineral rights where commercial values may differ greatly and which may be held by a multiplicity of holders? They argue that the tax would be contentious, wrongly burden the holding of rights intended for future use, raise the investment threshold, delay investment decisions, generate uncertainty about mineral right holdings and require considerable administrative effort. It could become a source of litigation, for example in so far as its application to property held in trust is concerned. In addition, such a tax directed at a policy purpose, as opposed to revenue generation, would be inconsistent with the guiding principles articulated by the Katz Commission and hence detract from the evolving coherence of the country's fiscal policy.

ii. It is also contended that, if a tax on mineral rights were introduced, expenditure on market development (such as R & D on possible new products and promotion of long-term growth in the market) incurred by the taxpayer should be allowed as a credit against the tax liability, in addition to the current value of past prospecting-related expenditures. Proponents of this view observe that ownership of mineral rights affords the long-term predictability of security of tenure on which major commitment to future development depends.

1.3.5 The Need and Capacity for Change

Whilst the Government recognises that the system currently in place has some positive features, it concludes that the *status quo* must be changed with a view to achieving the policy objectives set forth in paragraph 1.3.2 above. Government believes that changes will be implemented on an incremental basis. Notwithstanding changes to the current mineral rights dispensation, the State shall guarantee security of tenure.

1.3.6 Policy Proposals

1.3.6.1 Ownership of mineral rights

i) Government recognises the inherent constitutional constraints of changing the current mineral rights system, but it does not accept South Africa's system of dual state and private ownership of mineral rights.

ii) Government's long-term objective is for all mineral rights to vest in the State.

iii) State-owned mineral rights will not be alienated.

iv) Government will promote minerals development by applying the "use it or lose it" principle.

v) Government will take transfer of mineral rights in cases where a holder of mineral rights cannot be readily traced or where mineral rights have not been taken cession of and are still registered in the name of a deceased.

1.3.6.2 A new system for granting access to mineral rights

As a transitional arrangement in persuance of the objective stated in section 1.3.6.1 ii above, the following new system for granting access to mineral rights will apply:

i) The right to prospect and to mine for all minerals will vest in the State.

ii) Government will develop detailed legislative proposals for the introduction of the new system of access to all mineral rights. In developing such proposals provision will be made for:

a. prospecting and mining rights to be made to the first qualifying applicant and in cases of competing applications such rights will be granted on merit;

b. security of tenure by granting prospecting and mining rights for specified periods which are capable of cancellation or revocation only for material breach of the terms and conditions of the right;

c. registerable prospecting and mining rights which will be transferable with the consent of the State;

d. the holder of a prospecting right to be entitled to progress to a mining right on compliance with prescribed criteria and work commitments;

e. annual minimum work and investment requirement to discourage the unproductive holding of prospecting and mining rights;

f. a retention licence which may, upon written application, be granted to the holder of a prospecting right in cases where the holder, having explored the area and established the existence of an ore reserve which is, at the time of completion of the exploration programme, considered to be uneconomical due to prevailing commodity prices (market conditions) or where the exploitation thereof might lead to market disruption not in the national interest. Such licence will enable the holder thereof to retain the reserve without the commitment to minimum work and investment requirements. The licence will be granted for a limited period in respect of the property concerned;

g. precluding the issue of a prospecting or mining right over an area in respect of which a currently valid prospecting or mining right is held for the same mineral;

h. predetermined standard terms and conditions, for all prospecting and mining rights;

i. the reduction, as far as possible, of discretionary powers by applying standard requirements or objective criteria;

j. payment of compensation by the holder of the mining right to the registered holder of mineral rights. Such compensation will be payable in the form of royalties as determined by the State. No distinction will be made between royalties payable to the state and those payable to private holders of mineral rights. The quantum of royalties will be internationally competitive and will not inhibit the initiation of new projects;

k. payment of a surface rental, determined by the State, by the holder of a prospecting or mining right to the registered land owner; and

l. the approval of an Environmental Management Programme prior to the issue of a prospecting or mining right.

iii) Persons, including their successors in title, or assigns or nominees, who could lay claim, under section 43 of the Minerals Act, 1991, to the exclusive right to prospect for a mineral to which the right was reserved to the State, shall after the lapsing of the period that ended on 31 December 1996, or the approved longer period, no longer be deemed to be the sole holder of such rights.

1.3.6.3 Reconnaissance work

A non-exclusive licence for broad-based, non-destructive exploration will be implemented. Such licences will be for a limited period in respect of the area required. A reconnaissance licence will not entitle the holder thereof to a prospecting or mining right.

1.3.6.4 Disclosure of prospecting information

It will be a condition of any prospecting right or reconnaissance licence issued or renewed that all information and data from prospecting shall be submitted to the State after completion or abandonment of any particular prospecting activity. The State will release such information to the public at any time from the date of submission of such information unless the prospector retains a prospecting or mining right in respect of the land concerned or an application therefor is pending. Such information submitted to the State will be used to create a national exploration data base.

1.3.6.5 Data base of mineral rights holdings

Government will apply, through the Departments of Land Affairs and Minerals and Energy, greater resources to expediting the process of the compilation of a readily-accessible data base.

1.3.6.6 Tax on mineral rights

Government will investigate the feasibility of imposing a mineral rights tax or other mechanisms which would be intended to discourage the non-utilisation of privately-owned mineral rights. Such investigation, which will be undertaken by the Department of Minerals and Energy in association with the Department of Finance, will take into account the findings of the Katz Commission which is giving attention to this matter.

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1.4 Small-scale Mining

1.4.1 Background

i) A flourishing small-business sector usually increases competitiveness in an economy and is an efficient vehicle for the creation of jobs. The fall in the real price of minerals has led to the closure of numerous large-scale operations. Well-managed small-scale mining has the potential to take over and mine economically where large-scale mining is unable to operate profitably. In this way small-scale mining can make a meaningful contribution to the total global production.

ii) The development of small-scale mining alongside mining in underdeveloped regions would also increase the portfolio of minerals being produced and could lead to the exploitation of resources that would otherwise be sterilised. In addition, it could provide a channel for increased access to the mining industry.

iii) For the sake of clarity, the concept of small-scale and artisanal mining needs to be defined. There are significant potential environmental and health and safety problems associated with artisanal mining, which is often the only means of subsistence available to individuals. By artisanal mining is meant small-scale mining involving the extraction of minerals with the simplest of tools, on a subsistence level. There is no generally agreed definition of the term small-scale mining - although it is often defined with regard to mine's output, capital investment, numbers employed or managerial structure. Small-scale mining is a relative term; thus the choice of limiting criteria to distinguish between small and larger-scale mining (such as production rate, capital and labour employed) will differ from commodity to commodity and from country to country. In South Africa, small-scale mining ranges from very small operations that provide subsistence living (artisanal mining), to the 'junior' companies for which revenue is such that subsistence living is not the prime motivator.

iv) In many countries with large mining industries, both small and large exploration and mining companies compete aggressively and successfully side by side. This allows for the exploitation of small (low capital) and large (high capital) projects and provides opportunities for more entrepreneurial operators.

v) Worldwide, it is apparent that many new and major ore deposits have been located by small and lean exploration companies, who make decisions efficiently and rapidly. Typically these companies locate deposits and either sell them off to larger companies or, because they wish to be involved in the mining phase, enter into joint ventures with larger companies which provide expertise and/or capital to develop the project. This provides a healthy synergy between large and small operators.

vi) The interests of the country and the community demand that all forms of mining, whether large, small or artisanal, should be subject to the same requirements in respect of licensing, safety, health and the environment.

vii) Small-scale mining already takes place on a sizeable scale in South Africa. Opportunities for small-scale mining projects are found mainly in gold, diamonds, coal, industrial minerals and in minerals derived from pegmatites. These opportunities are often confronted by problems, such as:

a. access to mineral rights - the present South African mineral rights ownership system is seen by many as a major blockage in the development of small-scale mining.

b. access to finance - financiers are seldom willing to participate in small-scale mining ventures which often provide limited security and financial returns.

c. incoherent structure - there is a lack of appropriate structures that assist small-scale mining development.

d. location of operations far from major markets.

e. lack of management, marketing and technical skills - new small-scale mine operators face technical barriers to participate in mining, including lack of skills in dealing with aspects such as complex metallurgical processes, practical mining problems and business skills.

1.4.2 Intent

Government will encourage and facilitate the sustainable development of small-scale mining in order to ensure the optimal exploitation of small mineral deposits and to enable this sector to make a positive contribution to the national economy.

1.4.3 Policy Requirements

1.4.3.1 Views of small-scale miners

i. Small-scale miners require information on the availability of mineral rights and mineral deposits.
ii. Access is required to mineral rights and to the surface areas necessary to exploit these rights.
iii. Unfragmented and adequate information is required on mineral regulations, geology, mining and environmental aspects and mineral marketing.
iv. Technical assistance and training is required for small-scale miners in the broad spectrum of mineral-related activities.
v. Access to investment financing is required.
vi. Regulations in respect of mining should be relevant, understandable and affordable to the small-scale miner and should be enforced in a site-specific manner.
vii. Administrative procedures should be simplified and speeded up.
viii. Institutional research and development in respect of all the aspects of mineral development and exploitation relevant to small-scale mining is required, as well as the transfer of this technology to small-scale miners.
ix. Tax and royalties rates, levies and financial guarantees for rehabilitation should not constrain the development of small-scale operations.
x. An integrated and co-ordinated approach is required from all the government departments and other agencies to promote and develop small-scale mining activities.
xi. A co-operative and supportive approach towards the small-scale mining sector is required from the other sectors of the mining industry.

1.4.3.2 Other views

i) Minimum standards in respect of the environment should be maintained for all mining operations.

ii) Other land-use options should not be curtailed by small-scale mining activities.

iii) Health and safety standards and the rights of workers should be maintained in small-scale mining operations.

iv) Development of the mineral potential of especially the underdeveloped regions of the country is required.

v) Communities should be consulted regarding mineral development and should enjoy lasting benefits from such developments.

vi) Government should promote and encourage small-scale miners to operate within sound business principles.

vii) The deleterious effects of artisanal or subsistance mining on the environment and on safety and health elsewhere in the world, dictates the necessity for research in this area. Meanwhile, resources need to be employed by the State to control artisanal mining as effectively as possible.

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1.4.4 Policy Proposals

1.4.4.1 Mineral rights

i) Information on mineral rights and mineral deposits available for development will be made accessible, particularly for the benefit of small-scale miners.

ii) Mineral right holders will be encouraged through relevant legislation and other measures to make potentially mineralised areas that are not being utilised, available to other developers, especially small-scale miners.

1.4.4.2 Access to finance and technology

i) Access to funding for small-scale mining will be encouraged and facilitated through appropriate and targeted institutions.

ii) The costs of state advice and support for the small-scale mining sector will be weighed against the benefits of the application of such support to other mining or non-mining activities.

iii) The Department of Minerals and Energy (DME) will co-ordinate needs-driven research by the Science Councils and ensure that this information and technology is accessible to the small-scale mining sector.

iv) The DME, in consultation with private industry, organised labour, non-governmental organisations, tertiary institutions, research organisations and foreign aid agencies, will investigate the establishment of training facilities for small-scale miners, not only in South Africa, but in the region as a whole.

v) Information on all aspects relating to mineral development and exploitation will be made available by the DME by means of a 'one-stop shop' approach.

vi) All spheres of government and development agencies will work towards co-ordinating their activities in respect of the promotion of small-scale mining activities.

vii) The line functions of the DME will be restructured and enhanced in order to efficiently facilitate access to support small-scale mining on the broad spectrum of activities involved in such endeavours.

viii) Government will facilitate the mutually beneficial co-existence of big and small-scale mining operations.

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1.4.4.3 Regulation and administration

i) Mining regulations will be administered consistently, while adopting an approach of guidance and advice towards small-scale miners.

ii) The DME, in conjunction with other relevant Government departments, will streamline the regulatory and administrative procedures in respect of mineral exploration and exploitation.

iii) Health and safety standards will be maintained in small-scale mining operations.

iv) Processing of the Environmental Management Programme Reports (EMPRs) will be expedited.

1.4.4.4 Environmental management

i) Small-scale mining, like the rest of the mining industry, will be required to adopt measures that will promote environmental sustainability by means of the application of consistent standards and acceptance of the 'polluter pays' concept.

ii) Government will support the provision of training and skills development for small-scale miners in environmental management.

iii) Intensive environmental management guidance will be provided in areas where there is a high concentration of small-scale miners.

iv) Financial guarantees for rehabilitation will be flexible and site specific.

1.5 Mineral Beneficiation

1.5.1 Background

i. The term beneficiation, used broadly to describe the successive processes of adding value to raw materials from their extraction through to the sale of finished products to consumers, covers a wide range of very different activities. These include large-scale and capital-intensive operations like smelting and technologically sophisticated refining as well as labour-intensive activities such as craft jewellery.
ii. Through adding value or beneficiating mineral resources a country can maximise the rent it derives from exploitation of its natural resource base and have it serve as a foundation for further industrial development.
iii. For many decades, where there have been viable opportunities, the mining industry has invested in mineral beneficiation. However, South Africa has the potential to increase the proportion of mineral output that is beneficiated by virtue of its large reserves, technological skills and low energy costs.
iv. That South Africa has an abundance of raw materials available for beneficiation is not sufficient, or even necessary, for

beneficiation to take place economically here. Other factors on the demand side need to be taken into account too, of which proximity and access to markets are the most weighty.

v. Economic and fiscal certainty is required for the long-term planning needed for developments of the magnitude of mineral beneficiation projects.
vi. Raw materials prices paid by local beneficiators should not place them at a disadvantage in relation to overseas competitors.
vii. Stable and competitive tariffs for electricity and the transport of beneficiated products are required.
viii. Hurdles to beneficiation include a limited local market for beneficiated products, high capital costs and a lack of technology in certain fields.
ix. Due to a combination of factors, the real prices of numerous minerals have declined over the past four decades, leading to a general deterioration in the terms of trade for raw material exporting countries, as well as appreciable volatility in export revenues.

1.5.2 Intent

The aim of the policy will be to develop South Africa's mineral wealth to its full potential and to the maximum benefit of the entire population. Government, therefore, will promote the establishment of secondary and tertiary mineral-based industries aimed at adding maximum value to raw materials.

1.5.3 Policy Requirements

1.5.3.1 Views of the mining industry and minerals industry

i. Beneficiation projects should be initiated on the basis of market forces and decisions taken by individual companies pursuing well-considered business objectives.
ii. Demand-side factors, such as relationships with existing customers, should be taken into account in respect of mineral beneficiation.
iii. Measures instituted to promote mineral beneficiation should not be detrimental to the international competitiveness of the mining industry in respect of unbeneficiated mineral exports.
iv. Raw materials prices should be determined by the market and not by Government.

1.5.3.2 Other views

i. Due to the risks inherent in large-scale mineral beneficiation projects, supply-side incentive measures should be instituted by Government to promote value-adding activities.
ii. Policies and regulations that constrain the acquisition and ownership of precious metals and minerals by jewellery manufacturers should be reviewed.

1.5.4 Policy Proposals

i) A greater degree of co-operation and co-ordination will be established between the Departments of Minerals and Energy and Trade and Industry in respect of mineral beneficiation.

ii) In order to promote mineral beneficiation, efficient supply-side measures will be introduced, such as lower royalty rates for projects that include beneficiation. Qualification for such incentives will, however, require a commitment to promote further local downstream beneficiation through, inter alia, export parity pricing of products.

iii) Government is committed to promote investment in mineral beneficiation activities through ensuring competitive and stable costs of public services and goods, such as electricity and transport.

iv) The State will continue to support research with a view to developing new or improved beneficiation techniques and to developing new applications for locally produced mineral products.

v) Non-confidential information that could promote the beneficiation of South Africa's minerals held by Government departments and parastatal research organisations will be effectively disseminated to the private sector.

vi) Science Councils and Government departments will endeavour to establish joint-venture research and training programmes with universities and the private sector in order to produce the necessary skilled and productive manpower required for mineral beneficiation developments.

vii) Decisions regarding beneficiation projects will be based on sound economic principles.

viii) Prices for minerals and processed mineral products will be determined by the market.

ix) Policies and regulations that constrain the development of the local jewellery manufacturing industry will be reviewed by the Department of Minerals and Energy and other departments and institutions involved.

1.6 Minerals Marketing

1.6.1 Background

i. South Africa possesses an exceptional mineral endowment. The role that mining plays in the economy and the share that minerals contribute to exports, define South Africa as a minerals-based economy.
ii. The minerals industry energetically promotes, markets and sells its products domestically and internationally on competitive markets.

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1.6.2 Intent

Mineral marketing policy will be based on market principles. Government's role will be supportive, and intervention will generally be limited to addressing market failures.

1.6.3 Policy Requirements

1.6.3.1 Views in favour of state intervention in marketing

i. Government intervention in respect of minerals marketing should be limited to protecting the national interest.
ii. Transfer pricing should be dealt with by law enforcement.
iii. There may be merit in researching co-ordinated marketing of certain commodities as a means to increase foreign exchange earnings.
iv. The potential role of a mineral marketing audit office should be researched.
v. Consideration should be given to a small levy on sales to fund market development efforts.

1.6.3.2 Views against state intervention in marketing

i. The view that the State could match the marketing and sales performance of the private sector is contradicted by experience elsewhere in the world.
ii. Government intervention in minerals marketing is unwarranted and harmful and is emphatically opposed by mining companies.
iii. The establishment of a minerals marketing audit office is not necessary. The Reserve Bank has sufficient statutory power to regulate the flow of funds into and out of the country.
iv. The imposition of a levy on sales is opposed as an unnecessary additional form of taxation.
v. Minerals marketing is a private sector activity that is best handled by the producers themselves as has been done successfully throughout the years. There is no necessity for nor benefit in the establishment of a statutory minerals promotion body.

1.6.4 Policy Proposals

i) The marketing of minerals in South Africa will be determined by market forces. State intervention will generally be limited to addressing market failures.

ii) Barriers, economic and otherwise, to mineral exports will be identified and appropriate strategies for their removal will be devised. All measures which restrict the sale of South African minerals on foreign markets will be opposed.

iii) Transfer pricing will be dealt with by more efficient enforcement of laws. To this end co-operation and co-ordination will be established between the Department of Finance and the Department of Minerals and Energy.

iv) Government will encourage and support market development by producers.

1.7 Research and Development

1.7.1 Background

i. South Africa's diversity of mineral deposits poses a spectrum of technological challenges for the country's mining industry. World leadership has been achieved in the technology and practices to exploit the deep, complex and difficult mineralogy of many of South Africa's unique resources. Innovative solutions have been developed by the established mining houses and research institutions.
ii. Research and development in the mineral industry needs to conform to the development of a comprehensive science and technology policy that will address the country's needs. Policy in this regard is set out in the Science and Technology White Paper and tackles issues such as directing the country's research and development effort towards addressing the needs of its citizens, the balance between applied and fundamental work, redressing past discrimination in access to training related to research and development and the methods of funding these activities.
iii. A relatively large number of stakeholders representing a variety of disciplines perform research and development activities for the minerals and mining industry and these efforts need to be synergistic and complementary.
iv. The State is involved in research and development both as part of the national scientific and technological effort and on behalf of the industry through the CSIR, Mintek and the Council for Geoscience as well as at universities and technikons.
v. The Science Councils form part of the technology bridge between mining operations and available science, engineering and technology. It is here that the State's contribution is greatest.
vi. Co-operative research on health and safety is essential. The Leon Commission has commented on the role of the Safety in Mines Research Advisory Committee (SIMRAC) that the selection of research fields reflects a failure to apply a rigorous needs-based assessment and to carry out research related to occupational health.
vii. In instances where mining houses have identified advantages they have co-operated on research and development activities.
viii. Mining companies remain committed to research and development on process cost reduction and customer satisfaction, which serves their own interests and is funded by themselves, whilst recognising the potential contribution of user-influenced public sector research for common interests.

1.7.2 Intent

Government will undertake and promote research, technology development and technology transfer that will stimulate the optimal development of the country's resources in the longer term and ensure that the industry remains competitive.

1.7.3 Policy Requirements

1.7.3.1 Views of the minerals industry

i. Research and development undertaken by the State should be user influenced and complement private sector activity.
ii. Funding for the work of SIMRAC is provided exclusively by the mining industry. However, the Chief Inspector of Mines has control over the allocation of such funds and no limit exists on the funding for SIMRAC that the Inspector may demand of the industry. Such research should be funded in good part by Government. The costs of administering SIMRAC are to be borne by the public in terms of the Mine Health and Safety Act.

1.7.3.2 Other views

i) Appropriate fiscal incentives for research and development need to be developed.

ii) Focused and co-ordinated research on applied economic geology should be supported by Government and industry to attract new exploration companies to South Africa and locate new ore deposits.

iii) There should be a provision within the Mine Health and Safety Act to make levy funds available for the administration of SIMRAC activities.

iv) Capacity relating to the minerals and mining industry within various research institutions should be developed.

1.7.4 Policy Proposals

i) Research and development efforts will be directed to areas of high need to develop solutions in exploration, mining, processing and conservation and rehabilitation of the environment as well as methods to exploit the value adding potential of the country's minerals. This applies to large and small-scale mining.

ii) The recommendations of the Leon Commission on the restructuring of SIMRAC, ie the need for competent research management and overseeing of its programmes, will be implemented.

iii) Research on occupational health in the mining industry will, as recommended by the Leon Commission, receive due attention as part of the mine health and safety research programme.

iv) A system of matching grants will be considered for funding research and development projects.

v) Focussed and co-ordinated research on economic geology will be supported by Government and industry to attract exploration investment to South Africa.

vi) Co-operation between the various mining and mineral processing research and development institutions will be encouraged to make best use of existing facilities, to promote collaborative research efforts, to promote technology transfer and to ensure that minerals-related research and development is conducted in accordance with the country's science and technology policy and national objectives for the minerals industry. The results of the technology foresight exercise being conducted by the Department of Arts, Science, Culture and Technology will contribute to this endeavour.

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Chapter Two:
PARTICIPATION IN OWNERSHIP AND MANAGEMENT

Past legislation and practices have inhibited black ownership of assets, in mining as in other of the country's principal producing sectors. While various initiatives are under way to introduce black investors into the industry, ownership of the main mining companies remains as yet essentially unchanged. A long-term perspective is needed because of the difficulties of raising the large capital sums involved.

Similarly, workplace discrimination (legislated in some cases) obstructed the advancement of black people into middle and senior management positions in the mining industry. Progress has been made in recent years, both on the mines (notably via apprenticeship and other training programmes) and in head offices. But the impact will take some years to start being really visible because of the long periods needed for employees to acquire the practical experience required for promotion.

Black participation in ownership and management of the mining industry will have special political significance for South Africa's development as a market-based democracy.

2.1 Background

i) Government is unshakeable in its commitment to removal of racial discrimination in the workplace, in mining and elsewhere, through the bill of rights entrenched in the Constitution, as well as other supportive legislation.

ii) In similar spirit, Government believes that it will be profoundly in the interests of the economy for the mining industry to have a wider spread of ownership and to be regarded with pride by South African society in general.

iii) The Labour Relations Act (LRA) and other relevant legislation will assist in eliminating racially discriminatory practices at all levels within the mining industry. Mining companies have also taken steps to remove barriers to the advancement of black people and women in the industry. It will, nevertheless, require a considerable period of time before previously excluded groups can gain the technical and academic qualifications and experience that are required for the exercise of high level management and technical responsibilities in the mining industry. Government will continually monitor progress in addressing the racial and other imbalances and review whether intervention targeted at the mining industry is required.

iv) The Government has decided not to embark upon a programme of nationalisation to reverse ownership patterns in the mining sector.

v) The Labour Market Commission has recommended that steps be taken to facilitate worker participation in the organisation of work, as provided for in the LRA. These measures should create smooth industrial relations and facilitate workplace efficiency.

vi) The Mine Health and Safety Act, 1996 embodies a commitment to building a culture of co-operation in the workplace by establishing a range of tripartite structures. At mine level, health and safety committees consisting of employee and management representatives will promote workplace democracy as well as mine health and safety.

2.2 Intent

Government will encourage changes leading to equity of opportunity in respect of access to ownership and management of the mining industry.

2.3 Policy Requirements

2.3.1 Views concerning previously disadvantaged groups

i. The State should take a constructive interventionist role in altering the patterns of ownership in the industry and promoting black ownership at all levels.
ii. There should be a Workplace Anti-Discrimination Act that provides for an official audit of the extent of racial discrimination at every mine and puts in place a procedure, backed by law, to remove racial discrimination.
iii. The South African mining industry is heavily dominated by a small number of mining houses, all of which are white owned. Business ownership and control in the country in general, and particularly in the mining industry given its complexion should be deracialised. The mining industry needs to demonstrate rapid, visible and significant transformation in line with the rest of South African society.
iv. By virtue of their contribution to insurance and pension funds, mine employees and black people in general already have

significant financial interests in the industry. Such financial interests should be used to secure significant participation in the control of mining companies through exercising governance rights of shareholders.

v. Changes in ownership to achieve a broader spread as well as greater participation in managing mining companies on the basis of ownership should be promoted through the development of Employee Share Ownership Participation Schemes (ESOPS). Criteria used in developing ESOPS in the mining industry need to provide for genuine participation in managing operations, be of sustained value rather than linked to operations with a short life and be tailored for low income workers. Corporate initiatives around ESOPS are hampered by Income Tax laws and the Companies Act which should be amended so as to remove obstacles to such schemes.
vi. Due to the concentrated ownership that characterises the mining industry and in recognition of the long time that will be required for deracialisation of ownership to occur through market forces, specific initiatives are required to achieve effective deracialisation. A new form of corporate governance is required that will create conditions for effective employee participation through a system of co-determination.
vii. Development of the small-scale mining sector resulting from companies disposing of unwanted properties to black-owned companies or through the State purposefully allocating its mineral rights to black-owned companies will not produce genuine economic empowerment as this will be confined to small deposits or to future mining and will not address the inequity in the present distribution of mining industry ownership.

2.3.2 Views of the investment community and mining companies

i. Participation and ownership issues are of general application and should not be at the core of mining and minerals policy.
ii. Market forces dictate ownership of mining companies. Investment in public companies is open to everyone. Principally via insurance and pension funds, people of all races already have significant financial interests in the industry.
iii. The evolution of a wider spread of ownership will take place through market processes. Over the past few years a number of black-led financial companies have emerged with the resources to get involved in the large-scale sector, and various transactions are under consideration in the small-scale sector too. Some large corporations are actively facilitating these processes. It is only a matter of time before such developments come to fruition on a meaningful scale.
iv. Removal of discrimination is already well advanced via legislative and regulatory change supplemented by education, training, work reorganisation and other corporate initiatives.
v. In general, especially given the country's demographics, effective participation by blacks in ownership and management will be far better achieved by encouraging investment and growth rather than by directives and controls.

vi. Consequently, while greater such participation is both essential and welcome, there is no case for government intervention to achieve it. Radical changes to the system of corporate governance are similarly unwarranted: generic reforms are already well under way in the light of the 1995 report of the King Committee on Corporate Governance.

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2.4 Policy Proposals

i. Government will continuously promote a wider spread of ownership and seek to facilitate acceleration of the changes that are already under way.
ii. Consequently Government will consider the introduction of specific initiatives such as those set out below:

a) Government will facilitate steps to deracialise business ownership and control by means of focused policies of black economic empowerment. In the mining sector, State intervention through parastatal development finance institutions (including the Industrial Development Corporation and the Development Bank of SA) to finance investment in new and existing mining ventures in partnership with black companies will be encouraged.

b) Employee Share Ownership Participation Schemes are a practical vehicle to promote a broader spread of ownership and participation in mining companies. Government will facilitate such changes by adjusting the administration of tax and company law to reduce obstacles to establishing ESOPS for low income workers. (The third Interim Report of the Katz Commission "very much supports the objective of greater employee share ownership in South Africa," and states that ESOPS should include "the entire labour complement of a company ... particularly employees at the lower level of the organisation").

iii) Government will encourage real worker participation in the management of all mines.

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Chapter Three: PEOPLE ISSUES

The mining industry provides jobs for over half a million people directly, and for many more when both up- and down-stream multiplier effects are taken into account. The industry has created towns and nodes of economic development throughout the country. Because of the nature of the work, especially in the very deep mines, the industry has provided large numbers of employment opportunities for less skilled workers, from South Africa itself and from the region.

The labour situation in mining has been associated with the most controversial aspects of colonial and apartheid rule. These include pass laws, compounds, the migrant labour system, the reservation of skilled work for white people, and the denial of trade union rights to black workers up until 1982. The special control of mine labour and application of racial domination in the industry pre-dates the apartheid era by three-quarters of a century.

Reform began, slowly at first, in the early 1980s. While the process of change has accelerated in the past few years, the legacy of decades of discriminatory practice cannot be eradicated overnight - indeed the impact of some reforms will take a good many years to be fully visible.

Across the labour market as a whole, Government has embarked upon a programme of legislation that will ensure that the momentum of change is maintained. The tripartite approach embodied in the National Economic Development and Labour Council (NEDLAC) and other relevant statutary bodies should help underpin the process of constructive engagement among the concerned parties.

Improving relationships between people in the industry, allowing opportunities for human development and addressing the need for a safer and more healthy working environment are essential if the mineral wealth of the country is to be used to its greatest potential. At the same time, the industry has shed almost a third of its jobs in the last eight years and this trend of shrinking employment levels, in the gold sector in particular, is likely to continue, although its timing and scale cannot be accurately anticipated. A major challenge lies ahead in managing the social consequences of downscaling in the industry - which extends to linked industries and to urban and rural communities all over Southern Africa.

3.1 Mine Health and Safety

3.1.1 Background

i. The current fatality, injury and disease rates in the South African mining industry are unacceptably high.
ii. Following the 1995 report of the Leon Commission of Inquiry into Health and Safety in Mines, Parliament has passed the Mine Health and Safety Act, 1996. It is hoped that this will lead to a significant improvement in the health and safety profile of the South African mining industry.
iii. At national level, tripartite institutions have been established in terms of the Act. These institutions will continually influence policy development and law on matters relating to health and safety in line with the provisions of the Mine Health and Safety Act:

a) The Mine Health and Safety Council will advise the Minister of Minerals and Energy on health and safety at mines.

b) The Mining Qualifications Authority will advise the Minister of Minerals and Energy on education and training policy in the mining industry, in line with the Mine Health and Safety Act of 1996 and the South African Qualification Act of 1995.

iv) The Mine Health and Safety Inspectorate has been restructured as a separate branch under the Chief Inspector, within the Department of Minerals and Energy.

v) At mine level, the manager is required by the Act to develop and implement a health and safety policy, based on the officially approved policies set at national level and in consultation with health and safety committees at the mine which include management and employee representatives.

vi) The health and safety policies that are developed at national level and mine level are implemented within a context that is laid down by the Act:

a) In pursuance of a health and safety culture each mine must establish a policy that will incorporate the employees' rights set out in the Mine Health and Safety Act:

1. the right to representation and participation;
2. the right to education and training;
3. the right to health and safety information;
4. the right to leave a dangerous working place.

b) All employees have the responsibility to:

- take care of their own health and safety and safety of others who may be affected by their activities;
- use and take proper care of protective clothing, and other health and safety facilities and equipment provided for that purpose;
- report any situation which presents a risk to the health or safety of persons;
- comply with the provisions of the act.

vii) Previous legislation did not, in practice, address the occupational health care and compensation problems of mineworkers.

viii) The spread of HIV/AIDS through the workforce is likely to be a feature of the mining and other industries over the next decade and beyond.

ix) There are health and safety problems associated with small-scale mining which the current legislation and government policies do not adequately address.

3.1.2 Intent

Government will promote healthy and safe working conditions in all mines and deal humanely with the health consequences of work in the mining industry.

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3.1.3 Policy Requirements

3.1.3.1 Views of the employers

i. Policy should have as its objective the creation of an affordable, equitable and sustainable health-care system for employees.
ii. It is imperative that regulations governing safety in mines should be realistic and practically enforceable and are focused on areas where they are most needed.
iii. Health and safety in mines should be regulated by Acts of Parliament.
iv. Employees must accept the obligation to comply with safety standards.
v. Government should develop a national HIV/AIDS plan in consultation with all stakeholders.

3.1.3.2 Views of labour

i. Trade union representatives should be included in decision making on health and safety matters.
ii. Health and safety training for employees should take a priority position in the training programmes of the mines.
iii. The capacity of the Department of Minerals and Energy to deal effectively with health and safety issues needs to be upgraded urgently.

3.1.3.3 Other views

i) The State must recognise the cost to society and especially to rural communities of disabled and ill mineworkers and ex-mineworkers. It must be recognised that these persons have little or no chance of re-employment and must rely on disability payments or pensions.

ii) The State must recognise the health and safety aspects associated with small-scale mining.

3.1.4 Policy Proposals

i. Government will expedite the full implementation of the Mine Health and Safety Act and the recommendations of the Leon Commission.
ii. Government will, in consultation with employers and labour, develop a programme in the mining industry that ensures the physical, psychological and vocational rehabilitation of disabled workers to enable them to earn a living.
iii. A national database on occupational health will be developed that reflects the prevalence and incidence of occupational disease among mineworkers and ex-mineworkers. (Policy in

regard to currently employed mineworkers will be developed by the Mine Health and Safety Council (MHSC) in terms of the Mine Health and Safety Act. Policy for ex-mineworkers will be developed by the Department of Health in consultation with the MHSC).

iv. Government will, in consultation with employers and labour, review the system of compensation payouts to mineworkers and ex-mineworkers in the light of increases in the cost of living.

v. The system of implementing proper medical care for disabled and diseased ex-mineworkers will be reviewed

vi. A coherent and comprehensive policy towards HIV/AIDS will be developed by the State in consultation with the stakeholders as part of a national policy. Government will address the manner in which epidemiological research into HIV/AIDS is conducted; and specifically the manner in which mineworkers are tested, and counselled, educated and treated.

vii. The International Labour Organisation Safety and Health in Mines Convention will be referred for consideration to the National Economic Development and Labour Council and the MHSC before ratification by Government.

viii) Whilst maintaining health and safety standards in the small-scale mining sector, Government will review current legislation to ensure that the relevant provisions are practically applicable.

ix) Government has accepted that a properly structured system of administrative penalties could be more effective than a system of criminal enforcement in achieving the ultimate goal of the Mine Health and Safety Act, which is to improve health and safety in the mining industry. In this regard, Government will, in consultation with employers and labour, introduce an appropriate system of administrative penalties into the Act to replace, in respect of certain offences, the current system of criminal sanctions.

3.2 Human Resource Development

3.2.1 Background

i) The mineral industry has been characterised by racism in past practices of job reservation and in restricted access to training and advancement. Problems that are present, but not confined to the minerals industry, are a poorly developed human resource base and a concentration of skills and positions of responsibility in the hands of whites.

ii) The advancement of black workers and professionals into positions of seniority and into management in the mining industry has been limited.

iii) The majority of mineworkers have not had access to education and training opportunities and, as a result, the majority are functionally illiterate. This situation has a negative impact on safety and health standards and on productivity.

iv) In recent years, many mining companies have made efforts to redress past discrimination and to ensure that individuals with potential have the opportunity to reach higher levels of responsibility in the industry. Although aggregate statistical evidence is not yet to hand, individual mining houses report that a good majority of their apprentice artisans, learner-miners and other trainees are black and that, given the country's demography, this situation will continue into the foreseeable future. Over and above expenditure on training for purposes of ensuring a more productive and safer workforce, individual mining companies have invested in the education of communities connected to their activities. Up until now, training provided by mining companies has been, perforce, fragmented and lacks national standardisation. This situation is being addressed by the South African Qualifications Authority Act.

v) The Mine Health and Safety Act provides for the establishment of a Mining Qualifications Authority (MQA) which will advise the Minister of Minerals and Energy on education and training policy in the mining industry.

vi) A more comprehensive concept of human resource development which aims to have a more efficient, productive and better paid workforce through education and training is being adopted by all role players. This will upgrade the quality of life of the entire workforce.

vii) The Leon Commission has found that it is unsatisfactory to use Fanagalo as the language of the mines, because the language has a very limited vocabulary. While it may be satisfactory for giving simple commands it is quite inadequate to convey the nature and extent of the dangers that lurk beneath the surface, the source of such dangers, and how best to avoid them.

3.2.2 Intent

Government will encourage, support and facilitate human resource development in the mining and mineral industry.

3.2.3 Policy Requirements

3.2.3.1 Views of the employers

i. Primary responsibility for education from the basic to the advanced level lies with the State through the academic and vocational education system.
ii. For a competitive industry, South Africa needs an education and training system which provides a high quality secondary and tertiary education to meet the industry's operational and strategic needs in a cost-effective manner. The learning system should provide employees with flexible skills and attitudes to contribute to the profitability and safety of the enterprise.

3.2.3.2 Views of labour

i. Full union participation in structures dealing with education and training issues, from mine level to industry level, is essential.
ii. Education and training needs to incorporate a new set of values reflecting democratic change in the country.
iii. Education and training programmes provided by the unions should be recognised by the State and by mine employers. Union committees should have access to proper facilities from which to conduct their duties in the workplace. They should have access to training venues and equipment in order to conduct steward and membership education and training.
iv. Educational subsidies, including contributions from the mining industry, should be made available for the study of disciplines related to mining in line with general policies on support for technical and vocational training.
v. An industry training fund should be established via a small training levy on the mining industry wage bill. Mining companies providing or funding recognised training should be refunded from the training fund.
vi. In line with the National Qualifications Framework, on-mine training programmes and capacity building should be adapted to incorporate life-long skills and to provide flexibility in workers' career paths to assist miners to find post-mining employment in the context of downscaling and mine closure.

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3.2.3.3 Other views

i. Entry of black students to minerals-related fields of study needs to be promoted to overcome the legacy of past discriminatory practices.
ii. Hardships caused by job losses due to retrenchments and mine closures need to be ameliorated through appropriate education and training programmes to provide affected workers with enhanced employment possibilities, whether within the mining industry or elsewhere.

3.2.4 Policy Proposals

i. Government will support and promote provision of appropriate education and training in the mining industry. Particular emphasis will be placed on Adult Basic Education and Training (ABET), and health and safety training at all levels.

ii) ABET will be aimed at the following:

a. to provide workers with an education and training base for further learning and career path advancement;
b. to enhance health and safety in the workplace;
c. to develop workers' skills and understanding to enable them to participate more actively in the process of change within the workplace and the community;
d. to contribute to the removal of all discriminatory barriers within the industry, particularly those of a racial nature.

iii) The Department of Minerals and Energy will continue to promote representivity and redress past imbalances in selection of staff and in its support for internal education and training.

iv) Government will discourage the use of Fanagalo as a medium of communication in the minerals and mining industry. The language policy of the mining industry will be guided by the multi-lingual reality of South Africa, and constitutional rights regarding language.

v) Government will require that all learning achievements in the minerals and mining industry are registered on the National Qualifications Framework, to enable people to progress through various learning pathways, across levels of learning, and throughout their lives.

vi) Funds of the Mining Qualifications Authority will consist of monies appropriated by Parliament; monies collected in terms of the Mine Health and Safety Regulations and other applicable laws; fees obtained from services provided by the MQA; and any other monies received from any other source.

vii) Government will ensure that people in the minerals and mining industry have access to quality education and training so that they can gain the knowledge and skills they need for work and to improve their lives.

3.3 Housing and Living Conditions

3.3.1 Background

i. Hostels have been a significant feature of the system of labour on the mines since the birth of the modern mining industry in the late nineteenth century. Workers were often forced to live in austere, regimented single-sex hostels, subject to strict legal and extra-legal controls.
ii. The housing and living conditions for many workers in the mining industry are sub-standard. These conditions impact adversely on their health, productivity and well-being.
iii. The hostel system for black workers has been run on racial and ethnic lines and has been discriminatory.
iv. Progress has been made in upgrading hostel accommodation which has, in some instances, included the provision of married quarters.
v. Since mining operations are frequently located far from existing settlements, the provision of housing has been undertaken by employers as part of the infrastructure required to develop the mine. South Africa is unusual among the world's major mining countries in the provision of accommodation by employers.
vi. There is merit both in continuing to provide accommodation (and to upgrade accommodation), within the constraints of costs, and in encouraging and facilitating home ownership/rental by employees within nearby communities.
vii. The large number of workers housed in hostels and the costs of converting such accommodation requires a planned and phased

approach to improving mineworkers' living conditions. The principles of choice and full consultation with key stakeholders should apply to the planning and implementation of upgrading of accommodation and living conditions.

viii. The whole structure of mining towns and settlements must be altered to integrate mineworkers into the local economy and to end the racially discriminatory provisions that apply to housing for black mineworkers.

3.3.2 Intent

To seek to ensure that all employees have a choice in their pursuit of suitable housing and living conditions.

3.3.3 Policy Requirements

3.3.3.1 Views of the employers

i. Accommodation should be affordable and sustainable.
ii. Financing schemes used to improve mineworkers' living conditions should be based on payment for services rendered.
iii. Housing is part of remuneration and is settled by collective bargaining.

3.3.3.2 Views of labour

i. A range of tenure types should be offered to workers including rental accommodation, home ownership and social housing. Housing options should include single and family accommodation, accommodation in nearby settlements where feasible, and accommodation in mineworkers' home areas. The principle of choice for mineworkers over a wide range of flexible housing options should apply.
ii. Existing hostels on mines should be converted over time into family units and into single units for miners without families, or who elect not to live with their families. Included in the provision of family housing should be community and education services and facilities.
iii. Every mine should, in conjunction with representative trade unions, be required to draw up a five-year plan for the improvement of living conditions for workers, incorporating specific targets.
iv. The management of hostels must be democratised so that residents participate jointly with mine management in all areas of decision making around running the hostels.

3.3.3.3 Other views

The provision of family housing should be associated with expanded community services and facilities, including education.

3.3.4 Policy Proposals

i) Government will, in consultation with the Mine Health and Safety Council, propose measures regarding the standard of housing and nutrition of employees who are accommodated at mines. These measures should include the monitoring of compliance.

ii) Government will investigate the improvement of housing and accommodation for workers and their families at mines, with due regard to the sustainability of communities thus established.

iii) State assistance for both the upgrading of hostels to single accommodation and the conversion of hostels to family housing will be investigated.

3.4 Migrant Labour

3.4.1 Background

i. The system of migrant labour for black workers in the mining industry is deeply entrenched in the industry and within communities that have supplied labour for the mines, in some cases for over 120 years.
ii. The system was used by the mining industry to provide labour at low wages and low cost for the labour-intensive work on the mines. At the same time political, economic and social factors affecting rural communities throughout Southern Africa made migrant labour in many instances the only option to generate income.
iii. Migrant labour is associated with a range of negative consequences including the denial of normal family life to migrant workers, poor living conditions in single-sex hostels, and social disruptions including the break-up of marriages.
iv. The underdevelopment of parts of South Africa and of foreign countries supplying labour has created a situation of dependence on migrant labour for jobs and mineworkers' remittances. Approximately half the Gross National Product of Mozambique and Lesotho comprises mineworkers' remittances. As a result, individuals, communities and foreign countries have an interest in preserving the current system.
v. Mine employment patterns show a trend towards stabilisation of the workforce and a greater reliance on local recruitment. Despite such trends, migrant labour from rural areas within South Africa and from neighbouring countries will be a feature of mine employment for a long time to come.
vi. Migrant labour is an important topic that affects the mining industry. It is a complex issue that is under consideration by the Chamber of Mines, the Employment Bureau of Africa, the National Union of Mineworkers and the South African and foreign governments.
vii. The Labour Market Commission of 1996 considered a new approach for dealing with access to the SA labour market by non-South African nationals. The Commission:
    a. believes that the migrant labour system should be phased

out, but that in the process the terms of access of citizens of the Southern African region should be easier than for citizens of other countries;

b. finds that compulsory deferred pay arrangements constitute a human rights violation;
c. recommends that the current migration policy be thoroughly reviewed. Policy should be informed by a coherent set of non-discriminatory principles based on international norms. The revised policy will be effected by a single immigration statute governing the entry of all foreigners into the country.

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3.4.2 Intent

The system of circulating migrant labour will be regularly reviewed with the intention of minimising the adverse social consequences. In the longer term, Government will seek to phase out the migrant labour system.

3.4.3 Policy Requirements

3.4.3.1 Views of the employers

i. The principle of choice for employees and for employers over the offering and the engaging of labour should apply.
ii. Mining companies should have the right to hire workers from anywhere they choose without restraint, including all the countries in the region.
iii. Employers and employees should have the right to agree upon conditions of employment suited to their mutual needs.

3.4.3.2 Views of labour

i. There should be no discrimination against mineworkers on the basis of their geographical origin.
ii. Workers on South African mines should be granted the same rights and freedoms as all other workers in the country. Employers and foreign states should be prohibited from treating migrant workers as a special category as they have in the past.
iii. Employment contracts for mineworkers should be identical to those for all other workers. Workers and their trade union representatives should be entitled to re-negotiate their employment contracts directly with their employers and not be compelled to return home to do so.
iv. As the mining industry cuts its labour requirements through the increased use of technology and stabilises its workforce, it is likely that foreign and less-skilled migrant mineworkers will suffer most as they are the least equipped to deal with the consequences of job loss and have fewer job opportunities. It is important that the interest of these workers are safeguarded.
v. Use of foreign labour should be regulated. The regulation should be aimed at keeping the volume of labour from outside at

acceptable levels so that the region is supported in the process of addressing the endemic unemployment without unleashing anger in South Africa. However, people already working in the mining industry should have a right to retain those jobs.

3.4.4 Policy Proposals

i. The migrant labour system as it applies to the mining industry in its present form will be reformed.
ii. Government will convene a South African regional forum for multi-party consultation on changes to the migrant labour system in order to protect the interests of migrant mineworkers and to manage the effects on neighbouring countries and on labour-supplying regions within South Africa.
iii. Government will continue to permit citizens of the South African Customs Union countries and Mozambique access to the mining labour market on an acceptable basis.
iv. Government will instigate a review of the system of compulsory deferred pay with a view to it being phased out after consultations with affected parties. Voluntary deferred pay schemes will be permitted.
v. Foreign miners will have the right to be treated as any other potential immigrant to South Africa or temporary resident. Employers will be required to observe the regulations and protocols of immigration law in their hiring practices. All the rights and benefits of a particular category of employment will be enjoyed by foreign miners, including the right of temporary residents to bring accompanying dependants into the country. Migrants will be eligible for permanent residence or citizenship once they have worked in South Africa for the required period. Years worked will be deemed continuous notwithstanding the annual end-of-contract breaks.
vi. South Africa will subscribe to the International Labour Organisation conventions on migrant labour where relevant to the country's situation. Government will refer these conventions to the National Economic Development and Labour Council prior to their ratification.

3.5 Industrial Relations and Employment Conditions

3.5.1 Background

i) It is the duty of the State to create a framework that will facilitate a healthy and productive relationship between employers and employees.

ii) The Labour Relations Act provides a framework for industrial relations in the mining industry to take a less adversarial and more productive approach than has existed hitherto. This should underpin workplace efficiency and national economic growth.

iii) The Labour Market Commission has recommended that the Department of Labour establish a Section for Mining within the Chief Directorate: Labour Relations. This directorate would be responsible for facilitating smooth industrial relations in this industry and, in particular, for facilitating the establishment of workplace forums and councils and putting in place the necessary training and guidance infrastructure.

iv) In terms of the Mines and Works Act, mining on Sunday is prohibited. Essential maintenance work is allowed on Sundays. Additional work may be permitted by the Minister of Minerals and Energy "in the national interest". Extended operating times, not only in mines but in other sectors of the economy, has important employment creation potential. The prohibition on Sunday work in general and the regulation of working hours in the mining industry in particular, were seen by the Labour Market Commission as detrimental to the productivity of labour and capital.

3.5.2 Intent

Government will create a framework to facilitate a productive and non-adversarial approach to industrial relations and ensure that minimum standards apply to work in mining.

3.5.3 Policy Requirements

3.5.3.1 Views of the employers

i. All the necessary institutional arrangements are in place for meaningful discussions between employers and employees on all issues of mutual interest in the workplace. Any Government attempt to influence the balance between employers and employees could have serious implications, not only for the workplace partners, but also for Government itself.
ii. In the new approach to industrial relations and improvement in workplace conditions, relationships should encourage rather than inhibit workplace efficiency and flexibility in a balanced and performance-based system.
iii. Industrial relations matters are best left to arrangements agreed between employers and employees. Government should commit itself to ensuring a legislative and regulatory environment which secures opportunity for the workplace parties to settle their affairs without intervention.

3.5.3.2 Views of labour

i. The same basic conditions applicable to other workers should be extended to mineworkers.
ii. There should be a national job grading system, linked to a national minimum wage safety net. Profit sharing across the industry should be facilitated by new tax laws and tax paybacks to ensure that the 'same job, same pay' principle can be implemented across the industry. This system should be developed by a commission of inquiry under Government guidance. This will necessitate the formation of a National Bargaining Council for the mining industry, which should be encouraged by Government policy.

3.5.4 Policy Proposals

i. Government will investigate the feasibility of using the machinery of the Employment Standards Commission to set safety-nets to collective bargaining in specific sectors of the mining industry where statutory wage protection measures are not in force.
ii. Government will encourage the formation of workplace forums in every mine.
iii. Government will facilitate a process to establish a Bargaining Council for the mining industry.

iv) Government will review the current restriction of Sunday work. It will be guided in this regard by the findings of the Labour Market Commission, the result of negotiations between employers and trade unions, and the outcome of discussions between the Departments of Minerals and Energy and Labour.

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3.6 Downscaling

3.6.1 Background

i. Since 1987, the South African mining industry has shed over 250 000 jobs. A substantial number of jobs have also been lost in the industries supplying mines and providing goods for mineworkers and mining communities. The social costs of this process have been huge. The remoteness of many mines and their dominance in local economies make mine downscaling a particularly destructive process. A disproportionate burden of suffering has been and is being borne by workers and their families in rural areas, which have, for generations, supplied labour to the mines and in mining towns.
ii. Mining involves the extraction of finite resources and there inevitably comes a time when a mine must close. Up until 1987, mine closures were more than compensated for by the expansion of existing mines and the establishment of new operations. This pattern has now been broken. The depletion of ore reserves, combined with labour-saving technology required to improve competitiveness, will ensure a contraction of mining employment for the foreseeable future. A decline in a long-established mining centre has enormous knock-on effects for regions and for provinces, particularly when volatile economic events dictate the pace of contraction.
iii. Government policy on the national management of the social consequences of industrial restructuring is currently under review within the National Economic Development and Labour Council.
iv. The Labour Market Commission has recommended the adoption of a social plan approach to structural job losses such as those which are at present a feature of significant parts of the mining industry.
v. The social plan may encompass a wide range of interventions,

some in the traditional areas of "active labour market policy", others in the areas of regional/local economic development and rural development. It is an attempt to ameliorate the significant social disruption generated by structural employment loss and, more ambitiously, to create a formulation for future development both of individuals and of communities and localities. Social plans must be stakeholder driven, and firmly rooted in collective agreements and social accords. The following is proposed by the Commission:

a. an amendment to the Labour Relations Act to include specific reference to the negotiation of a social plan;
b. the development of a capacity within Government to advise on the structuring of a social plan and, in partnership with relevant industry training bodies, to facilitate training programmes;
c. the establishment of a Social Plan Fund to support strategies and programmes negotiated between employers and workers facing structural employment decline. State funding should only be provided to augment financial contributions negotiated between employers, unions, municipalities and provincial governments in a partnership to deal with the consequences of employment loss in a community.

vi) Substantial benefits would accrue to the country if mines could continue to operate profitably until their reserves have been fully exploited. It may be in the national interest to provide some form of temporary assistance to those mines which have the potential to bring to account their remaining orebodies profitably. These considerations obviously apply particularly in local areas dependent on the mining industry and therefore vulnerable to its contraction.

3.6.2 Intent

Government will endeavour to ameliorate the social consequences of sizeable downscaling and mine closure.

3.6.3 Policy Requirements

3.6.3.1 Views of the employers

i. Existing laws already require extensive consultation with the workforce in the event of significant down-sizing. The downscaling process, in all its aspects, is most appropriately dealt with by collective bargaining.
ii. Employers need to be fully informed of existing government programmes that may be of assistance to retrenched workers.
iii. Because of the general level of unemployment and because of the remoteness of many mines, retrenched mineworkers often experience difficulty in finding alternative employment. Government has an important role to play, firstly, in co-ordinating counselling, training and other initiatives targeted at the retrenchees through existing government programmes, and

secondly, in providing an environment that encourages companies to equip retrenched employees with skills to enhance their prospects of finding jobs outside the mining industry.

iv. In addition, Government should facilitate the involvement of affected communities (including municipalities) in any process intended to deal with the consequences of mine downscaling and closure.

3.6.3.2 Views of labour

i. Employers have an obligation to keep the workforce informed of developments that may impact on employment security and to plan, jointly with government and labour, measures to preserve employment or mitigate the consequences of retrenchment.
ii. Labour proposes active state intervention to prolong the lives of mines and to protect the interests of workers and communities affected by forces that lead to mine downscaling. Proposals include:
    a. targeted assistance from the State to prolong the lives of marginal mines;
    b. a Government agency that will manage and co-ordinate processes related to mine downscaling;
    c. State stewardship of mines that are scheduled for closure within five years.

3.6.3.3 Other views

i. All spheres of government need to be fully aware of the likely pace, scope and effects of mine downscaling and to co-ordinate activities in this respect.
ii. Government needs to ensure that the requirements for environmental rehabilitation are properly met in the case of unplanned downscaling.
iii. Alternative economic uses for mine assets and the infrastructure of mining regions need to be investigated and promoted.

3.6.4 Policy Proposals

i. Government has an obligation to assist employers, employees, industry suppliers and mine-linked communities in anticipating and managing the consequences of large-scale job losses.
ii. Preserving mining employment
    a. Because unemployment in South Africa is so high, every effort will be made to preserve employment in mining for as long as is economically viable and socially desirable. This goal should recognise the benefits of maximum output and foreign exchange generated by the mining industry.

b) Employment will be best protected and promoted by creation of a business climate that recognises the fundamental importance of long-term profitability and hence that encourages investment.

c) Government will investigate whether public assistance should be available for mines and regions faced with downscaling and, if appropriate, to formulate guidelines for such assistance.

iii) Dealing with retrenchments and restructuring

a. Government strongly endorses the proposal that social plans capable of cushioning the impact of structural job loss be drawn up.
b. Urgent action towards drawing up social plans is required in those mining sectors and geographical areas where large-scale restructuring is underway or imminent. Legislative and institutional support for the drawing-up of social plans is required.
c. In the short term:
    1. Government will develop specific capacity to monitor and forecast trends in employment and output in the mining sector. The implications of this information will be reviewed on a regular basis by a tripartite meeting convened by Government.
    2. Government will draw up guidelines for the compilation of social plans on mine downscaling and closure to provide all parties with a check-list and a time frame that can be adapted to their specific needs.
    3. Government will develop capacity to initiate and facilitate the drawing-up of social plans (including appropriate and affordable counselling, retraining and adjustment assistance) in consultation with the relevant government departments and with provincial authorities and municipalities.
d. In the medium term:

    1. Government will introduce a provision that requires mining companies to notifiy Government in the case of retrenchments that exceed 20% of the workforce in any twelve month period.

    2. Government will entrust the Advisory Board contemplated in 6.3.4 below with the task of monitoring restructuring in the mining industry and providing recommendations and options for the Minister of Minerals and Energy.

    3. Government will investigate the establishment of Social Plan Trust Funds by companies on a tax-free basis similar to that which applies to the environment rehabilitation funds established by mining companies.

Chapter Four:
ENVIRONMENTAL MANAGEMENT

The inhabitants of South Africa have the constitutional right to an environment that is not harmful to their health or well-being. Everyone has the right to have their environment protected through reasonable legislative and other measures that prevent pollution, encourage conservation and ensure the ecologically sustainable use of resources, while promoting economic and social development.

To attain these goals it is necessary that all sectors of industry, including the mining industry, adopt environmental impact management measures that will promote environmental sustainability, ensure the application of consistent environmental standards and accept the application of the 'polluter pays' principle. In view of the complex and unique requirements of the mining industry, a sectoral regulatory and integrated environmental management approach is appropriate, with generally applicable environmental standards being applied.

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4.1 Background

i. Mining activities impact on the environment to varying degrees. Three areas stand out for policy and regulation:
   a. the environmental impact of exploration;
   b. the environmental impact over the life of a mine and the provision of financial assurances for current and future mine site rehabilitation;
   c. rehabilitating sites where mining activity has ceased.

   These aspects are recognised in current legislation and regulation.

ii. Development in South Africa requires the optimum use of all the natural resources of the country. Much needed economic development should not be impeded by unmerited pressures in respect of the environment. Action of this kind in the past has resulted in permanent sterilisation of viable ore bodies and loss of development opportunities. Conflicts must be settled in a spirit of trust and consideration and a reasonable approach by the parties concerned.
iii. Government will have to ensure that the costs of environmental impacts of the mining industry are not passed over to the community. This calls for:
   a. an increased public involvement which will create a greater awareness of environmental considerations;
   b. a co-ordinated and integrated approach to the planning, management and use of all natural resources;
   c. the implementation of realistic, effective and affordable measures and standards for environmental impact

management, the prevention or efficient management of water, soil and atmospheric pollution, and the rehabilitation of areas affected by mining operations;

d. ongoing research with a view to improving and strengthening the measures, standards and practices applied to managing the impacts on the environment and to control pollution.

iv. The principle of 'the polluter pays' is relevant to the regulation and enforcement of environmental impact management measures and standards.

v. The role of the Department of Minerals and Energy (DME) as both the promoter of mining and regulator of the environmental management of mining has been unjustly criticised. However, the DME has developed, *inter alia,* its own environmental impact management structures, expertise and specialist skills to address the mining industry's particularly complex environmental impacts and management requirements. The Department has created separate chief directorates to (a) promote and (b) regulate mineral development.

vi. Under the Minerals Act, prospecting and mining operations may not be conducted without an environmental management programme (EMP) in respect of the land concerned having being approved by the authorities. To assist prospecting and mining companies to comply with this requirement, the Environmental Management Programme Report (EMPR) was developed and has been approved for use in the mining industry. The EMPR covers a description of the pre-mining environment, a motivation for and detailed description of the proposed project, an environmental impact assessment, an EMP and other related aspects. Adequate consideration must be given to alternatives to mining. The EMPR incorporates not only an impact assessment, but also a management plan in relation to impacts.

vii. The principles and objectives that have been integrated in the White Paper on Environmental Management and of Biodiversity, are largely incorporated into this chapter. The mining industry has an important role to play in the furthering of the aims of sustainable development by not exploiting our limited mineral reserves in a wasteful manner and by ensuring that the transitional use of land for mining does not exclude its productive use by future generations. The mining industry must, furthermore, promote sustainable development by providing infrastructure and expertise for the country's future benefit. The environmental management policy should be directed to this aim.

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4.2 Intent

Government will provide for the promotion of mining and mineral development while maintaining and enhancing the environmental performance of the mining industry through the application of reasonable, attainable, affordable and effective measures and standards based on local needs and requirements, while taking due cognisance of international tendencies and developments with regard to environmental impact management practices, measures and standards. While accepting that the Department of Environmental Affairs and Tourism will play a broad co-ordinative lead agent role in the national context, environmental management for the mining industry will be addressed on a sectoral basis with the DME acting as the dedicated lead agent.

4.3 Policy Requirements

4.3.1 Views of employers

i. A balance should be maintained between encouraging economic development and preserving high standards of environmental management.
ii. Subject to the site-specific nature of the operation, uniform standards of environmental management should be applied across mining operations of varying scale so that all mining is conducted in an environmentally responsible manner. Artisanal mining, which has frequently caused severe environmental damage in other countries, should not be treated more leniently.
iii. In principle, there should be no area, other possibly than those which have been sterilised by proclaimed townships, where prospecting and mining are prohibited, but the degree of sensitivity of the area must affect the standards of environmental control exercised by the mining operation. Should an economically viable ore body be discovered in a sensitive area, approval to mine should be subject to the full assessment of environmental impacts provided for in the Minerals Act, in which the 'no project' option can be considered.
iv. Cognisance should be taken of the stage of economic development of the country in framing environmental regulations. Environmental protection legislation that follows the example of highly developed countries should be adopted with caution. Prospecting and investment in mining have on occasion been substantially diminished as a direct result of ever-higher standards.
v. Mining should be granted precedence in land use, while taking cognisance of environmental factors.
vi. Appropriate environmental standards should be set for different stages of mining so that low impact activities, such as prospecting, are not burdened with cumbersome regulations.
vii. The interdepartmental consultation required for approval of environmental management programmes should be facilitated and expedited through a 'one-stop shop' approach in which the DME acts as a lead agent and liaises with other departments, provincial authorities and interested and affected parties.
viii. Delays in obtaining environmental approvals should be eliminated through improved administration.

4.3.2 Views of small-scale miners

i. Government support should be provided for the education of small-scale miners on environmental management.
ii. Intensive environmental management services should be

provided in areas where there is a high concentration of small-scale miners. Measures should include providing technical and environmental management assistance and simplifying the procedures for complying with environmental management regulations. Explicit budgetary allocations should be made for this purpose.

iii. Rehabilitation procedures should be made more affordable by devising a more flexible system for providing the necessary rehabilitation moneys.

4.3.3 Other views

i. Conservation areas including parks, reserves, wilderness areas, and cultural and archaeological sites should be protected.
ii. The rehabilitation of defunct and derelict mines which are a risk to the environment, public safety and human health should be provided for by appropriate regulation.
iii. The environmental damage caused by the mining industry should be managed and contained irrespective of the size of the mine.
iv. It should be ensured that the rehabilitation of land for post-mine use is carried out to standards that permit its use for the purpose set out in the EMPR and that closure be granted only after satisfying that there are no foreseeable residual impacts that will be inherited by parties acquiring such land.
v. Communities directly affected by mining should be enabled to participate in environmental impact assessments studies at the planning stage.
vi. South Africa should comply with international environmental standards to meet international obligations.
vii. Concerns that the DME lacks capacity to enforce existing environmental provisions should be addressed.
viii. Environmental management for the minerals industry should be improved by expanding the scope of EMPRs, which presently address the physical environment, to include assessment of the impact on the social environment.
ix. A conflict of interest between the promotion of the minerals industry and the enforcement of environmental standards within the DME should be prevented by providing a clear separation of powers.
x. Land-use decisions should be based on economic efficiency and mining should not enjoy a claim to precedence.

4.4 Policy Proposals

i. In order to ensure that the mining industry is accountable for its actions and the DME for its decisions, environmental management will further be integrated into all phases (from conception to closure and beyond) of a mining operation. In this regard, Government will ensure that the environmental management policy for the minerals industry and the implementation thereof is sector-specific. There will be co-ordination in the shaping of such policy with other policies and policy processes.
ii. The 'polluter pays' principle will be applied in the regulation and

enforcement of environmental impact management measures and standards. Where, for historical or unpreventable reasons, no responsible person exists or can be identified, the State may accept responsibility or co-responsibility for the rehabilitation required. Government may also order that any person benefiting from such rehabilitation should contribute to the costs in such proportion as may be determined.

iii. A proactive approach will be applied in identifying environmental impacts associated with mining; by implementing a combination of environmental impact management measures to ensure that mining-related impacts are managed with optimal efficiency; by educating, especially small-scale and artisanal miners, on environmental management; by providing intensified State-regulation of areas where there is a high concentration of small-scale artisanal miners; and by allocating funds specifically for this purpose.

iv. A consistent standard of environmental impact management will be applied and maintained, irrespective of the scale of the operation, but in relation to the site-specific nature of the mine.

v. Equitable and effective consultation with stakeholders will be undertaken, particularly those communities directly affected by mining. Informed decisions will be made taking account of grassroots views on mining environmental issues, at planning stages and in the compilation of EMPs. Consultation will however not be taken to the extent where effective decision making is sterilised.

vi. The environmental impact management process, which includes the application of the required EMP and other impact management measures in the mining industry, will be strengthened by:

   a. providing clear guidelines on the process and sequence of events for its implementation;

   b. integrating the principles of Integrated Environmental Management and recognising the wide use of the term "environment" by including economical, social and environmental factors in all procedures;

   c. strengthening the efficient implementation of environmental impact management measures in building capacity to monitor pollution and compliance with requirements;

   d. expanding the scope of the process by integrating a combination of environmental impact management measures which will promote a holistic and cradle to grave approach.

vii) The principle of multiple land use will be adhered to in planning decisions and contending options will be assessed on economic, social and environmental grounds; provided that the decision process will give precedence to mining where it is justified, will accept the concept of sequential land use, and will take account of equity, economic efficiency and sustainability.

viii) The mining industry will be encouraged to reduce problems of pollution by promoting a culture of waste minimisation through creative employment of re-cycling, and re-use of waste products. This will also be favourable to job creation. Waste management and minimisation of waste will be performed as part of sectoral environmental management.

ix) A streamlined system for environmental approval will be employed, through interdepartmental consultation. There will be a single interface with the minerals industry (the 'one-stop shop' approach), where the DME acts as the dedicated sectoral lead agent with a clear separation of powers and responsibilities within the Department.

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Chapter Five:
REGIONAL CO-OPERATION

Sustainable development in South Africa depends in good part on sustainable reconstruction and development in Southern Africa as a whole. An element of Government's long-term thinking is the gradual integration of the economies of Southern Africa through the trade and investment protocols of the Southern African Development Community (SADC). The region has considerable mineral potential and therefore the mining sector has a particularly significant contribution to make to the economic development of the region. Mutually beneficial programmes have the potential in the short as well as longer term to yield benefits for the region as a whole.

Regional Co-operation

5.1 Background

i. International economic relations are increasingly influenced by the formation of regional trade blocks, such as those in Europe and North America, offering the advantage of co-ordinated policies, large markets and the free flow of goods and services.
ii. Southern Africa has immense mineral wealth and the region produces over a third of the world's supply of gold, diamonds, platinum-group metals, vanadium, chrome and cobalt as well as over a tenth of other important minerals such as copper, manganese, granite and zircon.
iii. Since its inception, the South African mining industry has had extensive involvement and interests in the region, recruiting labour, prospecting and conducting mining operations. Historically, mining has played a role in integrating the economies of Southern African countries. The industry can

provide the foundation for renewed economic growth in Southern Africa.

iv. With the demise of apartheid and the normalisation of relations with our neighbours, South African companies are re-entering the region with vigour. Care will need to be taken to manage South Africa's integration into the region's economy to prevent it unduly dominating and attracting resources away from smaller countries.

v. A protocol on co-operation and integration of the mining sector in the SADC has been adopted which should result in economic development, alleviation of poverty and the improvement of the standard and quality of life througout the region.

5.2 Intent

Government will encourage co-operation on mineral and mining matters amongst the countries of the Southern African region and base that co-operation on the principle of mutual benefit. It will devise policies to enhance South Africa's capacity to contribute to the development of the region. The objective will be to achieve an equitable, balanced and mutually beneficial order in Southern Africa.

5.3 Policy Requirements

5.3.1 Views of employers

South African mining companies, equipment suppliers and consultancies have technologies, expertise and services potentially in great demand in the region and the rest of the continent. South Africa's economy stands to gain from increased regional, continental and international co-operation. For profound and enduring economic benefits of co-operation to be realised, a phased removal of barriers to the free movement of labour, capital, goods and services needs to take place, without destabilising any of the countries involved.

5.4 Policy Proposals

i. South African mining and related companies will be encouraged to apply their expertise to tap business opportunities in the region and across the continent.

ii. Government will participate in the co-ordination of the policies of Southern African countries so that the region can benefit optimally from its mineral wealth by taking specific steps to:

   a. remove barriers to the movement of labour, capital, goods and services but in a phased manner that will avoid destabilising the countries involved;
   b. co-operate in the harmonisation of the minerals and related legislation in the region, including the harmonisation of mineral-related industrial and technical standards;
   c. encourage cross-border mineral processing, which optimises capacity utilisation and increases value adding in the region;
   d. foster regional co-operation in technology development;

this should be facilitated through the exchange of geoscience and mineral processing information, technology, facilities and expertise;

e. encourage co-operation in the development of human resources in the region by facilitating the upgrading of the institutional capacity of Southern African mining and geology departments at tertiary institutions, and by pooling resources in the form of laboratory facilities, research centres and institutions;

f) disseminate investment and exploration information among member countries.

iii) Government will work co-operatively with other governments, private industry and international agencies to address environmental concerns as well, as mine health and safety standards in respect of mining and minerals.

Chapter Six:
GOVERNANCE

In order to contribute to a competitive and sustainable minerals industry in South Africa, Government involvement should be focused on efficient and cost-effective resource management. This includes the mineral, human, and environmental resources of the country. Such governance will require both regulatory and developmental dimensions, but with a clear separation of powers in order to maintain transparency and equity.

The activities of the Department of Minerals and Energy (DME) must be responsive to the needs of stakeholders and transformation within the industry. In this respect a special duty rests on the Department, being charged with a national function with wide impacts throughout the country, to co-operate with all spheres of government. Furthermore, the principle of tripartitism and consultation, which is necessary for open and inclusive governance, should be accommodated. This should include the opportunity for other parties and individuals to constructively engage Government and the main stakeholders on matters of common concern.

Governance

6.1 Regulation and Promotion

6.1.1 Background

i. In order to promote, support and regulate minerals and mining it is essential that Government institutions are competent and efficient. Exploration and mining are high risk businesses and consequently it is important that individuals and companies are confident in their dealings with state institutions, and that decisions are made timeously and efficiently. If contracts are to be negotiated and investment mobilised it will be important that institutions respond rapidly and professionally.

ii. The governance of the mining industry involves a number of players, including specialised government agencies, such as the Council for Nuclear Safety and the Council for Geoscience and Mintek, that have a significant influence on the industry. At the level of central Government - in which a number of departments have an interest in the industry - it is the DME which has the primary role in governance.
iii. The Leon Commission proposals regarding restructuring in the DME in order to address safety and health issues, have been incorporated in the Mine Health and Safety Act of 1996. These will, therefore, not be discussed in this chapter, other than to note that certain provisions of the Act remain to be implemented.

6.1.2 Intent

The regulatory and promotional activities of Government will be conducted in a transparent and efficient manner in carrying out its brief to encourage the development of the mineral industry, and to regulate it for the benefit of all South Africa's people.

6.1.3 Policy Requirements

6.1.3.1 Views of the minerals industry

i. Sensible regulation requires an understanding of the nature and interrelated technical complexities of mining, making the existence of a single, central regulatory agency highly desirable. That agency should be the DME, working as necessary through its own regional offices.
ii. The Department should serve as the pivotal link between the industry and other government departments and regulatory agencies.
iii. Subject to any obligations to maintain confidentiality of private information, the DME should make adequate information available on all the aspects involved in mineral investment and exploitation.
iv. Mineral regulation and administration should be conducted efficiently and expeditiously.
v. The DME must be adequately staffed by skilled personnel.
vi. The structure of the DME must be such that it is accessible and responsive to all sectors of the mineral industry in all parts of the country, and that the span of control is not stretched.
vii. In order to improve access to and investment in the mineral industry, relevant government institutions should not only assume a regulatory role but should actively pursue a promotional role as well.
viii. Interdepartmental communications, particularly between the DME and the Departments of Environmental Affairs, Water

Affairs, and Trade and Industry, should be improved in order to decrease the potential for cross-cutting legislation.

ix. An overall review is needed of which organisations of government will best serve the industry. The review should focus, in particular, on efficiency and competence in the administration and functioning of government agencies whose activities have a direct bearing on the mining industry. Regulatory and service agencies of the government should be attuned and responsive to the needs of and constraints upon the industry.

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6.1.3.2 Other views

i. The DME should look after the interests not only of the minerals industry, but also of the communities in the areas where mineral exploitation activities take place.
ii. The racial and cultural make-up of the DME should better reflect that of the community.
iii. The DME should cultivate a culture of development and promotion of the industry and people associated with it as well as functioning as a regulatory body.
iv. No intermediate institutions such as minerals trusts, should be involved in the process of mineral regulation and administration.

6.1.4 PolicyProposals

The DME will be the lead agent for governance of the minerals industry.

i) The structure of the DME will, amongst others, provide for:

a. separate intra-departmental components and mechanisms to handle the promotion of the industry on the one hand and regulation on the other;

b. a separate structure, within the regulatory component, to control environmental management in the mining industry;

c. a separate mine, health and safety inspectorate;

d. the improvement of administrative procedures in respect of the granting of prospecting and mining rights;

e. the provision of a cost effective 'one-stop shop' information and advice service to the minerals industry; and

f. ongoing research, co-ordination and review of minerals and mining policy.

iii) Government will ensure that all associated institutions concerned with the minerals industry will be guided in terms of national objectives and priorities. To this end it will be a statutory requirement that representatives from the DME serve on the boards of such institutions.

iv) In particular, the Council for Geoscience should focus on serving as a national resource for South Africa that can make data available at nominal cost. This may require a review of the Council's mission and Government's funding policy towards this institution.

v) The staff composition of the DME will reflect the demographics of South Africa.

vi) In the process of establishing mining operations, the relevant mining company will consult the affected community, taking due cognisance of the local economic development needs and local intergrated development plans.

vii) Intermediate statutory regulatory institutions, such as minerals trusts, will be phased out.

6.2 National and Provincial Governments and Municipalities

6.2.1 Background

i. Mineral affairs are allocated to the national level. In the Constitution mineral affairs are not mentioned in schedule 4 stipulating functional areas of concurrent national and provincial legislative competence, nor in schedule 5 stipulating functional areas of exclusive provincial legislative competence.
ii. The Minerals Act provides for the Department of Minerals and Energy to regulate prospecting, the exploitation of minerals, utilisation of land and environmental impact studies whilst health and safety issues are regulated in terms of the Mine Health and Safety Act.
iii. Irrespective of the emphasis in the Constitution on national responsibility for mineral affairs, in practice the provinces, due to the wide range of functions they have, also impact on mineral affairs, and vice versa. Several provinces are keen to promote mining in their areas.
iv. Mineral affairs interact with the following functions referred to in schedule 4 or 5 of the Constitution: agriculture, environment, health services, local government, nature conservation, regional planning and development, soil conservation, industrial promotion, urban and rural development, and public works.
v. In view of the Constitution, it is important to ensure that uniform mineral management and regulatory standards be maintained throughout South Africa and that services provided by Government be rendered in an equitable manner.
vi. Constitutional provision is made for the equitable division of revenue raised nationally among the national and provincial governments and municipalities. This sharing of a national pool of revenue, which includes revenue from mining taxation,

involves intricate considerations which fall within the functions of the Financial and Fiscal Commission.

6.2.2 Intent

Government will ensure equal treatment and standards in respect of the management and regulation of the mineral industry in all the provinces of South Africa.

6.2.3 Policy Requirements

6.2.3.1 Views of the minerals industry and investors

i. Sensible regulation requires an understanding of the nature and interrelated technical complexities of mining, making the existence of a single, central regulatory agency highly desirable.
ii. Because of the way the industry has evolved, as well as the need for consistency of policy and practice across provincial and local boundaries, there should be minimal devolution of authority to separate provincial or lower level bodies. Such bodies should not be empowered to create laws or regulations which impact on mining.
iii. In cases where there is a need for issues to be dealt with at sub-national level, a consultative process with all affected parties is essential.
iv. The relationship between a mine and its provincial authority and municipality has many dimensions but the basic criterion should be that the authorities avoid undue involvement in the operations of a mine.
v. Where a mine uses services provided by a municipality such services should be charged for on an economic and equitable basis, governed by the costs of provision; mines should not be burdened with inflated prices designed to improve the financial position of the municipality.
vi. Where a mine supplies its own services or can obtain them competitively from a supplier other than the municipality, it should not be obliged either to pay rates in respect of such services or to acquire them from the municipality.

6.2.3.3 Views of provincial governments and municipalities

i. In order to guide or affect the economic growth and development process, some influence is required in the minerals arena, be it at legislative, executive or operational level.
ii. Mechanisms are required whereby the negative social and economic consequences of mine closures can be planned for and ameliorated.
iii. There is a clear need for integration of regional/local, DME and Department of Trade and Industry attempts to stimulate small-scale entrepreneurial activities.

6.2.4 Policy Proposals

i. The minerals and mining industry will be governed at national level through a single lead department.
ii. Services provided to a mine by provincial governments or municipalities will be charged for on an equitable basis.

iii) A formal mechanism will be established whereby provinces can engage with national government on mineral industry issues where these relate to agriculture, the environment, economic affairs and other relevant provincial competencies.

iv) Provincial governments and municipalities will have access to the expertise and information available in the DME and associated institutions.

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6.3 Stakeholder Consultation

6.3.1 Background

i. The mineral industry has been an important factor in the development of South Africa's infrastructure and much of its secondary industry. It is a major provider of employment and other business opportunities, both directly and through backward and forward linkages. In order for the mineral industry to play its required role in respect of economic growth and the earning of foreign exchange, good co-operation will be required between Government, labour and the industry. This can only be achieved when policy formulation, management and regulation are conducted in an atmosphere of openness and in close consultation with stakeholders in the industry.
ii. South Africans recognise that there are large and complicated issues involved in mineral development activities. Development decisions affect the public in more ways than just providing employment opportunities. The stakeholders and affected communities should be involved in discussing all the issues surrounding mineral development activities and should participate in the decision-making process.
iii. The Mine Health and Safety Act includes a variety of provisions relating to tripartite consultation and co-operation in respect of different health, safety, education and training issues; these will, therefore, not be addressed in this section.

6.3.2 Intent

The management and regulatory activities of Government will be conducted in a transparent manner and will take into account the views and interests of all the stakeholders in the minerals industry.

6.3.3. Policy Requirements

6.3.3.1 Views of the minerals industry

i. An ongoing opportunity to debate all issues pertinent to mining and minerals policy, that would also provide a forum in which the views of other interested parties could be canvassed, is required. Such a structure and process are essential in order to achieve a collaborative approach to policy formulation, as well as to give coherence and focus to what could otherwise be a fragmented and insufficiently consultative approach to policy.
ii. The minerals industry will be promoted through information and education programmes relating to the contribution of the industry to the economy, the role of minerals in everyday life, and mineral-related issues such as the environment and safety and health.

6.3.3.2 Other views

i. A forum should be established where the views of communities affected by mining could be heard.
ii. A greater degree of co-operation and co-ordination between government departments is required, as well as between Government and the private sector.
iii. A tripartite forum is required to advise the Minister of Minerals and Energy on issues related to mining, such as the environment.

6.3.4 Policy Proposals

A statutory board will be established that will advise the Minister of Minerals and Energy on mining and mineral matters that fall outside the Mine Health and Safety Act. It will provide a forum in which government departments, representatives of the principal stakeholders, viz. business and labour, as well as other interested parties, can debate issues that bear upon existing or new policies.

Consultative Process Conducted by the Mineral Policy Process Steering Committee

The Steering Committee operated with a mandate to manage the process of mineral policy formulation in an open and transparent way allowing for full stakeholder participation. Three main consultative actions were organised.

Written Submissions	Bilateral Meetings	Public Workshops
Publication of *Discussion Document on*	Provincial Executive	Two workshops with

Minerals and Mining Policy for South Africa, November 1995	Councils: Mpumalanga	some 400 attending.
	Northern Cape	
Received 62 written submissions including 12 statements setting forth a vision for South Africa's mineral policy.	Western Cape	Wide range of stakeholders attended and aired their views:
	Northern Province	
	Free State	
Submissions made by employers, foreign mining companies, labour, communities, central and provincial government, professionals and interest groups.	Gauteng	Large and small mining companies
	North-West	Labour
	Minister of Land Affairs	New entrants
Further submissions made in course of bilateral consultations.		Small miners
	Minister of Water Affairs and Forestry	Foreign companies
	Department of Environmental Affairs and Tourism	Government officials
		Professionals
	Department of Finance	Traditional leaders
	Department of Labour	Organised agriculture
	Ministerial advisors to:	
	Deputy President Mbeki	
	Department of Trade and Industry	
	Foreign mining companies	
	Mining investment analysts	
	Environmental groups	
	Organised agriculture	

Views of stakeholders consulted in the course of preparing the Minerals and Mining Policy Green Paper

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Record of Mineral Policy Meetings and Submissions

Written submission made on the Mineral and Mining Policy for South Africa Discussion Document, November 1995

No	AUTHOR	TITLE	DATE
1	African National Congress	Draft Mineral and Energy Policy Discussion Document	Nov-94
2	African National Congress	ANC Vision Statement on Mining and Mineral Policy for South Africa to advance into the 21st Century	Jan-96
3	Association of Industrial Minerals Metals and Mining	Vision Statement on Mining and Minerals Policy for South Africa	Jan-96
4	Bafokeng Private Farms Association	Views on Housing and Living Conditions	Mar-96
5	Employers' Caucus on Mineral Policy	Mining and Minerals Policy in the New South Africa	Jun-95
6	Employers' Caucus on Mineral Policy	Review of South Africa's Minerals and Mining Policy	Jan-96
7	Council for Geoscience	Comments on the Policy Discussion Document	Jan-96
8	Council for Geoscience	Comment on the Discussion Document	Dec-95
9	De Beers	Discussion Document on a Mineral and Mining Policy for South Africa	Jan-96
10	De Beers	Submission for the Green Paper on a Minerals and Mining Policy for South Africa	Feb-96
11	FSA de Frey	Mineral Policy Discussion Document	Jan-96
12	Department of Finance	Discussion Document on Mineral and Mining Policy for South Africa	Mar-96
13	Department of Health	Discussion Document on Mineral and Mining Policy for South Africa	Feb-96
14	Department of Mineral and Energy Affairs	Draft Principles on which a mineral and mining policy for South Africa should be based	Nov-94
15	Department of Mineral and Energy Affairs	Vision for Minerals and Mining Policy for South Africa	Jan-96
16	Duard Barnard & Associates	Submission on Policy	Jan-96
17	Eskom	Eskom's Response to the Discussion Document on a Minerals and Mining Policy for South Africa	Jan-96
18	Exploration Targets	Mineral Policy Discussion Document	Jan-96
19	Falconbridge	A View of a Potential Foreign Investor in the South African Mining Sector	Nov-95
20	Federation of Mine Production Workers	Comment on the Discussion Document on a Minerals and Mining Policy for South Africa	Jan-96
21	Fidelity Investments	Discussion Document on a Minerals and Mining Policy for South Africa	Jan-96

22	Fleming Martin	Investor Perspective on the South African Minerals and Mining Industry	Jan-96
23	Gencor	Comment on the Discussion Document on Mining and Mineral Policy	Jan-26
24	Geological Society of South Africa	Comments from the Geological Society of South Africa	Feb-96
25	Inca Mining	Mineral Policy Discussion Document	Jan-96
26	FJ Kruger	Submission on Mineral Rights	Jan-96
27	G Levin	Commentry on Discussion Document	Jan-96
28	Lynette Dreyer & Associates	Comments on the Minerals and Mining Policy	Dec-95
29	Magaliesberg Protection Association	MPA Comments on the Discussion Document	Jan-96
30	MJ Martinson	Submission on Minerals and Mining Policy	Jan-96
31	Mercury Asset Mangement	Government Mining Policy	Jan-96
32	Mintek	Submssion for Green Paper on Minerals and Mining Policy	Jan-96
33	MJ Ellman & Associates	Vision Statement of the Minerals and Mining Policy	Jan-96
34	SJ Mongwaketse	Comments on the Mineral Policy Discussion Document	Feb-96
35	Mphahlele Traditional Authority	Review of the South African Mineral Policy	Sep-95
36	Mphahlele Traditional Authority	Submission on Disucssion Document	Jan-96
37	Mpumalanga Province Dept Economic Affairs & Tourism	Submssion on the Discussion Document	Dec-95
38	Mineworkers Union	Vision Statement by the Mineworkers Union	Jan-96
39	Mineworkers Union	Comment on the Discussion Document on a Minerals and Mining Policy for SA	Jan-96
40	Namagroen Prospecting & Investments	Comments on Behalf of Namagroen Prospecting and Investments	Jan-96
41	Namakwaland Kleinmyners Vereniging	Memorandum from the NKV	Sep-95
42	Northern Cape Province Dept Trade, Industry & Tourism	Comments on issues of concern w.r.t. minerals and mining policy for SA	Feb-96
43	B Nokwindla	Submission for the Green Paper on a Minerals and Mining Policy for SA	Jan-96
44	National Union of Mineworkers	Mining and Mineral Policy	Aug-95
45	National Union of Mineworkers	NUM's Vision for a Minerals and Mining Policy	Jan-96
46	North West Province	Submission to the IFG 23.10.95 Minerals and Mining	Oct-95
47	Public Service & Administration	Discussion Document on a Minerals and Mining Policy for South Africa	Dec-95
48	RMP Properties Services	Mineral Policy Discussion Document	Jan-96
49	Suid Afrikaanse Landbou	Kommentaar op die Besprekingsdokument in	Jan-

	Unie	verband met 'n Mynbou en Mineraalbeleid vir Suid-Afrika	96
50	Samancor	Mining and Minerals Policy for South Africa	Dec-95
51	SA National Defence Force	Discussion Document on a Minerals and Mining Policy for SA	Feb-96
52	Society of Designers in South Africa	Vision Statement	Jan-96
53	SA Guild of Goldsmiths, Society of Designers in SA	Policy Proposals for the Promotion of the SA Jewellery Industry	Jan-96
54	Shell South Africa	Discussion Document on a Mining and Minerals Policy for South Africa	Jan-96
55	Soekor	Minerals Policy Discussion Document	Dec-95
56	Steinkopf Small Miners Association	Submission from Small Miners Association Steinkopf	Jan-96
57	Stubbs Barbeler Grant	Submission on Discussion Document	Jan-96
58	A Theledi	Proposals and Recommendations Minerals and Mining Policy for SA	Jan-96
59	Taung Small Miners Association	Points to be raised	Dec-95
60	Trans Hex Group	Submission for the Green Paper on a Minerals and Mining Policy	Jan-96
61	JM van den Heever	Option 2 Submission on Discussion Document	Dec-95

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Bilateral Meetings

Party	Date
Mpumalanga Provincial Legislature MEC for Econmics Mr Mabena	31/01/96
Northern Cape Provincial Legislature Executive Council	14/02/96
Western Cape Provincial Legislature Executive Council	27/03/96
Minister of Land Affairs Minister Mr D Hanekom	09/04/96
Northern Province Executive Council	11/04/96
Economic Advisor to Deputy President Mr Ngoasheng	03/05/96
Special Advisor to Trade and Industry Dr Jourdan	17/05/96
Briefing to Kwa-Zulu Natal Provincial Legislature Cabinet Committee on Economic Affairs	22/05/96
Free State Provincial Legislature Executive Council	24/05/96
Department of Environmental Affairs and Tourism	28/05/96
South African Agricultural Union	28/05/96
Foreign owned Mining Companies	03/06/96
Mining Investment Analysts Managers International call conference	03/06/96
Minister of Water Affairs and Forestry Professor K Asmal	11/06/96
Gauteng Provincial Legislature MEC for Economics Mr J Moleketi's staff	26/06/96
Environmental Lobby Group	27/06/96
North West Provincial Legislature Executive Council	03/07/96

Department of Finance	12/08/96
Department of Labour	09/10/96

Further Written Submissions

No	AUTHOR	TITLE	DATE
62	BHP	Mineral Policy and Modern Mining Code Issues	18/03/96
63	Development Bank of Southern Africa	National and Provincial Powers	20/03/96
64	Amplats	Mineral Rights Ownership	16/04/96
65	The Mining Industry Employers' Caucus on Connepp	Towards a new Environmental Policy for South Africa	
66	The Wildlife Society of SA	Environmental Management	25/06/96
67	Non-Governmental Environmental and Land Organisations	Submissions	27/06/96
68	Mineworkers' Union	Sunday Work	01/07/96
69	Department of Land Affairs	Mineral Rights: Trust Lands	03/07/96
70	Falconbridge Limited	Access to land (mineral rights) and access to information (prospecting)	
71	Northern Province	Draft Minerals Policy Discussion Document	11/07/96

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List of Abbreviations and Names

ABET - Adult Basic Education and Training (see ABET National Interim Guidelines, Department of Education, September 1995)

Council for Science Council responsible for geological mapping, State earth science

Geoscience research and a repository of geological information

DME - Department of Minerals and Energy

EMP - Environmental Management Programme

EMPR - Environmental Management Programme Report

ESOPS - Employee Share Ownership Participation Schemes

Fanagalo - Dialect of commands combining various languages developed on mines early this century

ILO - International Labour Organisation

LRA - Labour Relations Act

MHSC - Mine Health and Safety Council

MQA - Mining Qualifications Authority

NEDLAC - National Economic Development and Labour Council

NQF - National Qualifications Framework

SADC - Southern African Development Community

SIMRAC - Safety in Mines Research Advisory Committee

TBVC - Transkei, Bophuthatswana, Venda and Ciskei

Legislation Cited

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- Income Tax Act no. 58 of 1962
- Kwa-Zulu Ngonyama Trust Act of 1994
- Labour Relations Act no. 66 of 1995
- Lebow Minerals Trust Act of 1987
- Mine Health and Safety Act no. 29 of 1996
- Minerals Act no. 50 of 1991
- Mines and Works Act no. 27 of 1956
- Restitution of Land Rights Act no. 22 of 1994
- South African Qualifications Authority Act no. 58 of 1995

Commissions Cited

Katz Commission: Commission of Inquiry into Certain Aspects of the Tax Structure of South Africa.

King Committee: The King Report on Corporate Governance, 1994.

Labour Market: Restructuring of the South African Labour Market: Report of the Commission

Commission of Inquiry into the Development of a Comprehensive Labour Market Policy RP83/1996.

Leon Commission: Commision of Inquiry into Safety and Health in the Mining Industry, 1994.

Margo Commission: Report of the Commission of Inquiry into the Tax Structure of the Republic of South Africa RP34/1987.

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DOCUMENT 4

Third Pacific Economic Cooperation Council Minerals Network Meeting

Tianyun, China - September 2005.

THE AUSTRALIA / INDIA MINE SAFETY TRAINING PROJECT

(An Australian Government Aid-Funded Project)

(This paper was originally presented with the permission of AusAID to the Executive Committee of The Indian Coal Forum in New Delhi, in December 2001).

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Abstract: *This project was performed under the Memorandum of Understanding, "Agreement on Development Cooperation between India and Australia" signed in 1990. In its initial phase the objective was to review the existing procedures and practices in mine safety in India and to update these based on contemporary practices in a country employing more advanced mining technology. Other objectives were to expose Indian Mines Inspectors (staff of the Directorate General of Mines Safety), to mining conditions and practices in Australia, and to train a number of inspectors in managing mine safety using techniques which render operators responsible for the health and safety of mineworkers in individual mines.*

The three-year program was extended by one year to provide a practical basis for the industry to appreciate the impact of modern safety management practices. At four mines, safety management plans were developed using criteria relevant to each mine and with mine management support, were monitored for changes in operational and attitudinal performance. Structured mine evacuation exercises were performed in two mines to test the effectiveness of existing practices and sophisticated equipment, to assist DGMS to identify hazardous and life threatening situations was provided and inspectors trained in its use. Emphasis was placed on the ability of DGMS to communicate freely internally between its offices and within the mining industry generally.

This paper focuses on the practical aspects of the "extension", the establishment of safety management programs at four mines, each employing a different mining technology and having safety problems typical of the employed technology. It was an objective of the project that these lessons be freely available to the industry with a view to having the benefits widely understood and the practices more generally used.

1. Introduction.

Historically, mining has been an important industry in India with recorded mining and mineral processing activities dating back more than 2000 years. In the twentieth century mining had become a significant industry satisfying an increasing domestic demand for metals and fuels. Substantial changes occurred in the post-Independence period, many of these being associated with the nationalisation of a number of mining operations. The application by successive governments of their own brand of politics and economics left a resource rich country lagging its competitors in mineral development policies and practices. With few exceptions, mining practices at this time and in some cases until much more recently, were those more readily identified with an earlier era. An immense population created a strong demand; incapable of being satisfied from local production, of both fuel and non-fuel minerals. Access to international markets with sales in foreign currency was denied because of an industry inability to maintain production at appropriate levels.

In 1994, the Government opened the metals sector to private industry. This was followed by a relaxation in the coal industry permitting private operators to mine coal, subject to its use in captive power stations. Today these restrictions are being further relaxed as India strives to maximise the value of its mineral resources. A number of major (and some junior) international explorers accepted the challenge and have become an integral part of the Indian mining scene. Mining practices, which until then were those of the Government enterprises, were subject to international scrutiny and the regulatory authority, established and operating under archaic conditions, was able to compare their record with that of more developed economies. In a number of respects, but particularly in respect of mineworker safety, the Indian industry fell far short of the achievements of most countries employing more advanced mining technology.

In September 1995, the Ministry of Labour of the Government of India requested the Australian Government (through their Bilateral Aid Program) to provide assistance to the Directorate General of Mines (DGMS). The assistance requested was to comprise training in upgrading the skills of Indian mines' inspectors and guidance in the methodology best employed by the Directorate. The concept was readily accommodated within the guidelines set out in an existing Agreement between the Government's of India and Australia signed in 1990. AusAID (the Australian Government's International Aid Agency) engaged a consultant to work with DGMS to define the parameters for a technology transfer project which would provide DGMS with a technical and legal basis for effecting major improvements in the safety record of the Indian mining industry. Out of this initiative, the India: Directorate General of Mines Safety Training Program evolved.

2. Project Background.

In March 1997, AusAID invited proposals from qualified Australian organisations to deliver the Mines Safety Training Program. A newly formed Australian company, Australian International Mine Safety Training Company Pty Ltd (AIMSTC) was contracted to deliver the project services. AIMSTC was established by three experienced mining consultancies, Geo-Eng Pty Ltd, Strata Control Technology Pty Ltd and SIMTARS (Safety in Mines Testing and Research Station, an entity within the Queensland Government's Department of Mines and Energy). The three companies brought to the new organisation; complementary skills and experience that would permit the delivery of the technical services required satisfying the project needs. An important feature of AIMSTC's planning was to involve the regulators of Queensland, New South Wales and Victoria in the project to allow DGMS inspectors to access their know-how and experience. The project was to be of three years duration and commenced on 1 July 1997. While both DGMS and AusAID had completed the broad project definition, AIMSTC's initial task was to plan in detail how the objectives could be achieved. Two visits were undertaken to India to allow Australian project personnel to assess mining conditions and the regulatory framework within which improvements were to be effected. Two visits were made to Australia by a number of members of senior management of DGMS to view relevant operations in Australia and for an exchange of views with Australian regulators. Out of these early visits and discussions a project plan evolved which addressed a range of activities which would be completed within a three-year time span. Each year's activities were further developed in successive Annual Plans. The program was to provide:

- exposure to Australian mine safety practices and technology;
- development of:
    - occupational health and safety standards and procedures;
    - codes of practice;
    - legislative standards;
    - mine safety information systems.

The Indian mining industry was under considerable pressure to increase production levels to meet the current and future demands of the country's growing economy. There was a need to increase the level of mechanisation and to introduce and apply new technologies and to do this within the ongoing liberalisation of the mining sector. DGMS saw their needs as including the exposure of their officers to new technologies, to modern developments in mining techniques and to mine safety management systems. They saw a need to review existing safety standards and regulations and safety practices and to develop and introduce new and appropriate safety standards.

The Australian Government perceived their role in the project as assisting DGMS to establish technically sound guidelines and regulations, standard testing procedures and standardised monitoring/design techniques. They also believed that the program could complement other (then) ongoing and planned projects between India and Australia in the coal-mining sector.

Both Governments believed mutual benefits would emerge from the program, including:

- for India, exposure to the most recent Australian industry safety practices and technology;
- the opportunity to adapt relevant Australian experience and practice, introducing this to the Indian industry;
- acceptance of new mining technology, thereby improving trade opportunities for Australian suppliers of mining services and equipment.

The program had as its prime objective, the improvement of occupational health and safety in the Indian mining industry. Its purpose was to provide a technical training program for DGMS officers, which would develop from their exposure to Australian technology and mine safety practices. It was expected that in the course of the program, enhanced occupational health and safety standards and procedures, new and revised codes of practice, upgraded legislative and regulatory standards and mine safety information systems would be developed. The four project components, each considered a specific project objective, were:

1. *Industry Familiarisation.* To expose senior officers of the India and Australian mining inspectorates to their respective counterparts' current industry safety practices and procedures and mining technology.
2. *Training.* To establish a training system which would provide and maintain an appropriate level of adequately trained DGMS personnel to support the development and implementation of new safety practices, systems and technology in the Indian mining industry.
3. *Development of Safety Standards and Systems.* To review existing safety standards, practices and legislative measures in different areas and, where appropriate, develop updated or new safety standards, procedures and systems.
4. *Management.* To establish a Project Coordinating Team to successfully manage, monitor and control the project.

Thirty DGMS officers were selected for intensive training. Training areas were agreed between DGMS and AIMSTC. Standards and systems were related to specific areas in which training took place. The eight main training areas around which detailed project activities were planned were:

- Longwall Face Support;
- Equipment Testing Standards and Approval Procedures;
- Underground Coal Mine Roadway Support and Pillar Extraction;
- New Technology in Hard Rock Mining;
- Open Cast Mining;
- Occupational Health and Safety;
- Mine Safety Management Systems;
- Environmental Management.

The initial objectives (substantially achieved in the initial three-year period) comprised:

Establishment of DGMS Institutional Training Program.

- DGMS officers were to be trained to be capable of managing the ongoing application and administration of new standards and procedures.
- DGMS officers were to be trained to a level whereby they understood and appreciated the technical criteria governing the application of the standards and procedures under various conditions.
- An in-house technical training group was to be established to ensure the continued application and support of new safety practices, systems and technology. DGMS trainers,

able to train DGMS personnel to maintain the institution's skills base and increase the numbers of trained personnel, were identified and prepared for their new roles.

Review of Existing Safety Standards and Systems.
DGMS officers, with guidance from AIMSTC personnel, were to review the existing DGMS safety standards, procedures and systems following exposure to Australian practices and the likely influx of new mining technology and systems into the Indian mining industry. This outcome was achieved through the interaction between DGMS, the AIMSTC project team and industry stakeholders, including mining companies and management, mineworkers and unions, authorised testing and approval stations and mining institutes. DGMS were to identify particular areas requiring the introduction of updated or new safety standards, procedures and systems and to plan for the introduction and circulation of these standards, procedures and systems.

Development of New Safety Standards and Systems.
It was anticipated that the review would show a need for new or updated standards, procedures and systems for, at least:

- requirements of support in longwall faces and underground roadways;
- code of safe practices and legislative standards;
- broad based mine safety information systems;
- standardisation of occupational health and safety parameters.

These objectives were largely satisfied as the project period drew to a close. AusAID had additionally authorised the procurement of a number of items of testing equipment, including intrinsically safe airborne dust sampling pumps, portable noise dosimeters, portable sound level monitors, portable noise loggers, portable gas monitors, portable blast vibration monitors and a Fourier Transform Infra-Red (FTIR) Spectrometer. DGMS laboratory staff were trained in their use and maintenance.

Although substantial progress had been made in upgrading the skills level of individual mines inspectors, concerns which had been expressed early in the program about the continuance in the industry generally of the new and revised approaches to mine safety, re-surfaced. AIMSTC emphasised in its dealings with mines (as well as with Inspectors) that worker safety is both a mine operator and an individual responsibility, and that mineworkers themselves must be aware of the difference between a safe and an unsafe working environment and, at all times, to work safely.

AusAID, in response to a further DGMS request agreed to extend the program for an additional one year with an emphasis on concept sustainability. The extended objective was to put in place at four selected mines (each using different mining technology), formal safety management systems developed by mine managements, with the cooperation and assistance of DGMS and AIMSTC. Progress at each of these 'model mines' would be subject to review and each mine would constitute a demonstration mine for the wider industry. The systems approach, using current industry risk assessment principles would survive the project, with the benefits demonstrated by improved operational and worker safety.

At two other mines, exercises emphasising mine emergency response and evacuation issues were to be coordinated, based on current Australian practice and existing mine procedures. The intention was to demonstrate the need for effective documented procedures at each mine that were fully understood by all mineworkers and which would permit a planned and safe response to any mining emergency.

This paper will review the introduction of the mine safety management systems into the four selected mines.

3. Implementation – Model Mine Program

To reinforce project outcomes, prototype Mine Safety Management Systems were developed by mine operating staff with the assistance of DGMS and AIMSTC. Four mines, each employing different extraction technologies and having different operating conditions and practices were selected for the introduction of a systems approach to mine safety, using internationally accepted risk assessment processes. Each mine, under the guidance of DGMS, designed and implemented a mine safety management program (MSMP). Each MSMP would be later reviewed for progress (against the plan) and tangible improvements in safety performance, monitored. It was anticipated that visible results would be achieved and that these mines would remain as 'model mines' illustrative of the benefits of applying contemporary management techniques to safety problems. The cooperation of the mine operator was readily obtained once the ongoing benefits were appreciated.

The model mine program was undertaken at the following four mines:

- No.1 - Vastan Mine, an open cast lignite mine owned by Gujarat Industries Power Company Ltd, Gujarat, in November 2000.
- No. 2 - Balaria Mine of the Zawar Mine Complex, an underground zinc (ore) mine, owned by Hindustan Zinc Ltd, Rajasthan, in March 2001.
- No.3 - Sendra Bansjora Mine, an underground bord and pillar coal mine, owned by Bharat Coking Coal Ltd, Madhya Pradesh, in July 2001.
- No.4 - Jhanjra Mine, an underground longwall coalmine, owned by Eastern Coalfields Limited, West Bengal, in August 2001.

Each of the model mines implemented selected and relevant mine safety management systems developed during the exercise. System development followed a process of hazard identification, risk ranking and determination of hazard controls and responsibilities in order to develop action plans for the identified hazards. The process employed is summarised below:

Step 1:	*Identify MECHANISMS by which hazard can occur.*
Step 2:	*Ranking of likely RISK.*
Step 3:	*Identify CONTROLS (existing and possible new) for reducing RISK.*
Step 4:	*Identify PROCEDURES for implementing and maintaining controls.*
Step 5:	*Identify RESPONSIBILITIES.*

The action plans constitute the basis for the development of the safety management plans.

Ranking of risk is accomplished by the use of a standardised approach that considers three components of mine safety and assigns a qualitative value representative of the severity of the risk. As long as each individual mine assessment uses consistent rating factors, the risk ranking demonstrates the impact of any individual occurrence. An example of the process is later included (Annex A), and in this instance the risk rating has been prepared using the risk factors as set out below (Tables 1, 2 & 3).

It was planned that some two to three months after the mine safety management systems and guidelines had been operating, a follow-up assessment and audit program would be performed by a team of mine personnel and DGMS project officers, assisted by AIMSTC specialists. As at the time of preparation of this paper, a review had only been concluded at the Vastan and Zawar (Balaria) mines. Reference is later made to this review (Section 3.5)

The example (Annex A) uses the conveying of ore in the Balaria Mine of the Zawar Group of Mine of Hindustan Zinc Ltd (MM #2). The potential hazards in this area are identified and assessed with regard to their risk. This plan does not address a principal hazard but rather an area of activity of the mine. For the purpose of the exercise, this was deemed to be adequate to demonstrate the principles involved and how such a plan should be drawn up.

IDENTIFIED HAZARDS
Safety Definitions
Hazard: *A source of potential harm or a situation with the potential to cause loss.*
Principal Hazards: *A hazard with the potential to result in multiple fatalities.*
Risk: *The chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.*

To bring all participants to the same level of understanding regarding the process, and to gain consensus regarding the terms used in the assessment, a risk assessment course was held prior to the exercise at each mine. Each risk assessment team consisted of a cross section of disciplines at the mine.

At the Balaria Mine, the risk assessment was conducted on the area which included the production inclines, Phases One and Two. This area is from the bottom of the bottom of the bunker at 75MRL to 250 MRL, the transfer bunker, and from 250 MRL to 380 MRL on to the primary fine ore bin where it is dumped.

The hazard identification process uses the principle that a hazard can also be defined as an unplanned or unwanted release of energy. Hazards were assessed in terms of risk, defined as the product of consequence, exposure and probability. In assessing the risk, the values for the consequence of the hazard it were based on the most reasonable worst case occurrence. Cognisance was given to controls already in place.

Table 1: Values used for Consequence

	CONSEQUENCE	RISK RATING
1	Catastrophe	100
2	Disaster	50
3	Multiple Fatalities	40
4	Single Fatality	20
5	Permanent disablement	15
6	Serious Injury	10
7	Lost time Injury	5
8	Medical treatment	2
9	First Aid	1

Arbitrarily, at Balaria, it was decided that hazards with a risk of above 400 would require immediate action. Those with a value below 400 but above 100 would be deemed to require attention, and those that were below 100 were acceptable, but required maintaining in order to keep them to this low level.

For hazards that require maintenance only, no controls were formulated, as the present controls were considered sufficient. For hazards that require attention, controls for improvement were formulated and for hazards that require immediate action, an action plan was drawn up.

Table 2: Values used for the Exposure of Workers

	EXPOSURE	RISK RATING
1	Continuous	10
2	Frequent (Daily)	5
3	Seldom (Weekly)	3
4	Unusual (Monthly)	2.5
5	Occasionally (Yearly)	2
6	Once in 5 years	1.5
7	Once in 10 years	0.5
8	Once in 100 years	0.02

Table 3: Values used for the Probability of the Occurrence Happening

	PROBABILITY	RISK RATING
1	Expected/almost certain	10
2	Quite possible/likely	7
3	Unusual but possible	3
4	Only remotely possible	2
5	Conceived but unlikely	1
6	Practically impossible	0.5
7	Virtually impossible	0.1

The Risk Assessment results and implications for the example are discussed in Annex A.

While standardised risk assessment procedures were employed at each mine, criteria were varied from mine to mine as the DGMS standard was still being developed. All risk assessment processes performed were internally consistent and the relativity of ranked identified hazards determined the priority with which hazards were addressed. The process was evolutionary also, and Model Mine No. 1 proved in many ways to be a test case, providing a basis for refining the processes employed for later mine visits. It also was the first of the series of mine visits to which DGMS Inspectors were exposed and this introduced some additional uncertainties of process. Notwithstanding, the exercise at the Vastan Lignite mine focussed on hazards peculiar to that mine and set out a management regime which led to improvements in a number of the less satisfactory activities, in terms of safety, associated with the mine. This mine, together with the second visited have been reviewed and it is pleasing to note the improvement resulting from the attention given by mine management to identified hazardous areas and practices. These are referred to in more detail in Section 3.5.

3.1 Model Mine No.1 – Vastan Lignite Mine

At the Vastan Lignite Mine introductory discussions focussed on hazard identification and on the principles and systems available for the management of safety and occupational health in the workplace. Regardless of the system employed, common principles included:

- A high level of management commitment and leadership;
- A recognised framework of OH&S across the entire workplace;

- Connection by all personnel to the OH&S system;
- Implemented safe work practices which (as a minimum) match regulatory requirements;
- Preparedness to handle emergency events;
- Investigation of accidents and removal of any dangerous situations;
- Record keeping;
- Continuous improvement;
- Openness to internal and external audit.

The processes by which these are achieved comprise:

- Regular OH&S meetings involving mine-wide representation;
- Regular reviews of work activities and equipment design and operation;
- Improvements to reduce OH&S impacts in high risk area or activities;
- Action management;
- Audit work.

To introduce the Risk Assessment technique as a means of ensuring resources can be directed to the most pressing (or most serious hazardous) concerns, mine site staff were exposed to a Safety Checklist as a basis for hazard identification as part of the assessment/ranking process. The Safety Checklist for the Vastan mine included the items and activities detailed in Table 4.

At the Vastan mine, technical presentations were made on three aspects of mine operations identified during mine inspections and discussions, as most relevant to safety issues at the mine. These were the concept of Risk Management, issues concerning Slope Stability and Integrated Mine Planning. A Risk Management Workshop involving both mine and mine contractors' staff. explored the processes of hazard identification, risk prioritisation, control method identification and action plan preparation – all specifically related to conditions prevailing at the Vastan Mine. Workshop teams addressed two different issues, Slope Stability problems (of concern because of slope failures endangering a nearby village), and Integrated Mine Planning. This latter Workshop concluded that more short term planning was required to better manage the development of mining areas, haul roads and external and internal dumps. The Workshop also concluded that the mine planning software capability was not being fully utilised.

The outcomes included a listing of hazards, a recommended treatment, identification of implementation issues and an action list. Hazards identified for which actions were recommended included:

- Dumper operation in foggy conditions;
- Haul Road crossings;
- Minimisation of fire risk during refuelling;
- Unauthorised personnel and vehicles on site;
- Minimising risk of tyre inflation ring flying off dumper tyre during inflation;
- Slopes stability issues associated with the future eastern slope;
- Minimising potential for head injuries;
- Ensuring safe and efficient performance of regular maintenance activities;
- Manual work component of tyre changing; Regular reviews of safety of operations.

Of specific concern at this mine, and a problem at many open cut mines in heavy rainfall areas, is the serious hazard to mine workers and to mine equipment as a result of massive slope failures. It is possible to reduce the risk of such failures by specialist geo-technical investigation and testing, and slope design, a much-preferred approach to adopting traditional slope angles based on previous failure experience in assumed similar ground conditions.

Table 4: Safety Checklist – Vastan Mine

ITEM	ACTION
Safety Induction	Establish and undertake safety induction briefing of all visitors to the mine. Establish, undertake detailed safety induction of all employees and contractors working at the mine.
Safety Training	Establish and undertake appropriate regular training in safety issues for each work group and/or work place. Establish safety guidelines for working in various locations, or with equipment.
Site Access Control	Establish and implement measures to control access to the mine, including: • restrictions on visitors and local farmers/residents to enter mine environs, • restriction of employees to high hazard areas, • traffic routes around the site for various types of equipment and vehicles.
Safety Equipment and Facilities	Ensure appropriate protective equipment is supplied and used by all employees. Ensure appropriate safety equipment is available in case of an emergency. Ensure access to appropriate medical treatment in case of an emergency.
Incident Reporting	Establish incident (accident and near miss) report forms. Ensure incident reports are prepared for each accident or near miss. Ensure each incident is investigated by appropriate staff and safety action recommended. Ensure hazard control actions are implemented and audited.
Hazard Identification	Establish hazard identification checklist to be used prior to commencing a job. Ensure checklist is used. Ensure appropriate hazard elimination/control measures are implemented prior to commencing work on the job.
Risk Assessment	Establish work risk assessment system on mine development and operations. Undertake job risk assessments Ensure required hazard control mechanisms are implemented.
Geo-technical Assessment	Establish geo-technical risk assessment for mine. Ensure potential failure mechanisms are identified. Ensure appropriate site investigations and material testing is undertaken. Ensure appropriate monitoring systems are established. Ensure potential failure mechanisms are analysed and appropriate mine design modifications are made to maintain acceptable stability and risk. Audit mine geo-technical conditions.

3.2 Model Mine No 2 - Balaria (Zawar Mine complex)

The mine site work program at the Zawar Mine Complex was divided into 3 components, each performed by a separate team. Teams were assigned to review:

- Risk Assessment and Mine Safety Management;
- Strata Control;
- Occupational Hygiene.

A risk assessment/safety management plan workshop was completed jointly by teams undertaking the first two assignments. The third team completed a separate program of work involving noise and dust surveys at a number of different sampling locations in the mine

The standards, guidelines and mine safety management systems identified, developed, implemented and recommended to the mine management as part of the Model Mine No.2 program (by each team) include:

Risk Assessment and Mine Safety Management Plans
Following the workshop, a risk assessment was completed on activities associated with conveying of ore within the Balaria Mine (refer Annex A, the example used for demonstrating the system). In this exercise, a number of hazards were identified as requiring attention. Three of those hazards were identified as requiring immediate action and action plans were formulated for:

- control of respirable dust at the mine;
- reduction of risk of falls of persons'
- prevention of transformer/distribution control box fires.

The team prepared a Safety Management Plan for Dust Hazard Control. The plan identified the resources and responsibilities for implementation. It was recommended that mine management implement the plan and that the other Safety Management Plans identified be formulated and implemented.

Strata Control
Following the workshop on risk assessment and development of mine safety management plans, a risk assessment on the Strata Control issues for stoping operations at Balaria Mine was completed. Subsequently, a Stoping Strata Control Plan was developed which outlined in general terms the implementation and management of issues identified in the risk assessment. The mine was to complete and implement this plan. The AIMSTC/DGMS/Balaria Mine team recommended that further assessment, development and implementation is undertaken for:

- the development of a Strata Management Team;
- the development of Stoping Hazard Plans;
- an assessment of pillar stability;
- an assessment of regional mine stability – in the Western Stopes;
- the development and implementation of monitoring protocols and response guidelines.

Occupational Hygiene
A series of underground and surface dust and noise field surveys was completed at the Balaria Mine. Based on the survey results a Safety Management Plan for Occupational Hygiene and Occupational Health, Dust and Noise Management was prepared.

Recommendations were developed which outline the resources and actions required over the next 3 months for the implementation of the management plan.

3.3 Model Mine No 3 - Sendra Bansjora Colliery

The mine site work program at Sendra Bansjora Colliery comprised two components, each being undertaken by a separate group. The components were:

- Mine Fires;
- Inundation.

A 2-day joint risk assessment workshop was first completed, mine fires and inundation being the identified high-risk hazards for which safety management plans would be developed. Each group undertook a process of detailed hazard identification, risk ranking and determination of hazard controls and responsibilities in order to develop action plans as the basis for developing safety management plans.

Action plans for Mine Fires and Inundation developed during this work program are now part of the mine operating procedures.

Standards, Guidelines and Systems.
The standards, guidelines and mine safety management systems implemented and/or recommended to mine management for implementation included prioritising the procedures developed as part of the Mine Fires Safety Management Plan and the Inundation Safety Management Plan.

Mine Fires.
From a risk assessment for mine fires at Sendra Bansjora Colliery, a number of hazards were identified as requiring attention. These included:

- Seam IV Isolation Trench.
- Other Procedures - several procedures relating to the control/prevention of mine fires already exist but many do not exist or are not documented. It was considered that it should be possible to develop and/or document the majority of these procedures prior to the planned review.
- Mine Fires Safety Management Plan - these identified procedures will form the basis for the Mine Fire Safety Management Plan to be developed and implemented.

Inundation.
From a risk assessment for inundation, a number of hazards were identified as requiring attention. Three hazards were identified as requiring immediate action and action plans were formulated for:

- Pillar failure due to fire, allowing connection with surface water body (Ekra Jore);
- Failure of river bank during heavy rain;
- Failure of drift dam, 10 to 11 Seams.

Action plans were also developed for:

- Surface flooding or water body entering through goaf or mine entries;
- Barriers against flooded old workings failing under hydrostatic pressure;
- Accidental holing into old flooded workings.

The order in which the identified procedures are to be developed was based on the risk ranking. Those procedures associated with the 3 hazards requiring immediate attention would be developed and implemented first. The identified procedures will form the basis for the Inundation Safety Management Plan (to be developed and implemented).

Safety Management Plans.
In order to assist with the on-going development of the mine safety management plans, AIMSTC provided Sendra Bansjora Mine a guideline for standards development of Safety Management Plans, prepared initially for the guidance of DGMS personnel. AIMSTC also provided DGMS and the mine team with a number of international technical papers on inundation of underground mines.

3.4 Model Mine No 4 - Jhanjra Colliery

The mine site work program at Jhanjra Colliery was divided into 2 components with each component being undertaken separately as follows:

- Strata Control;
- Mine Environment -Ventilation and Spontaneous Combustion.

A joint risk assessment workshop was conducted before undertaking the separate components. During the workshop, strata control and spontaneous combustion of coal in the underground workings were identified as high-risk hazards for which safety management plans would be developed. A process involving hazard identification, risk ranking and determination of hazard controls and responsibilities was followed to develop action plans for each identified hazard. Action plans for Strata Control and Spontaneous Combustion were developed during this work program.

Standards, Guidelines and Systems.
The standards, guidelines and mine safety management systems implemented and/or recommended to mine management for implementation included prioritising the procedures developed as part of the Strata Control Management Plan and the Spontaneous Combustion Safety Management Plan.

Strata Control.
A risk assessment for strata control at Jhanjra Colliery was performed for the development of the Strata Management Plan and arising from this, a number of hazards were identified as requiring attention, with priorities set based on risk assessment ratings. Procedures were identified that need to be developed to control these hazards. Several procedures relating to strata control in the mine already exist, but many others are not documented or do not exist. The majority of those procedures identified in the Action Plan as requiring to be developed or documented are to be completed prior to the December review. The procedures will form the basis for the Strata Control Management Plan.

Spontaneous Combustion.
A risk assessment for spontaneous combustion at Jhanjra Colliery was completed as part of the exercise. A number of hazards were identified as requiring attention and an Action Plan was formulated for the control of these hazards. The majority of the identified procedures relating to control of spontaneous combustion at the mine already exist, but many of the procedures were not documented. New procedures identified in the Action Plan requiring to be developed will be addressed, as will procedures that are to be documented, and all will form the basis of the Spontaneous Combustion Safety Management Plan.

Safety Management Plans.
In order to assist with the on-going development of the mine safety management plans, AIMSTC referred Jhanjra Mine to the previously provided DGMS Guideline for Development of Safety Management Plans.

3.5 Review/Audit of Model Mines 1 & 2.

Vastan Mine
In June 2001, some six months after the visit during which the initial risk assessment exercise was completed, a return visit was made to review those aspects of mine operations which were the subject of installed safety management programs. In general the result was pleasing. The following comments below were made following the review.

Hazard Control.
It was evident that substantial work had been carried out on the hazards identified in the initial visit. Discussions with management, staff and contractors confirmed that the high risk score hazards had all been addressed in varying degrees and control measures put in place. These included:

- increasing security of access into the mine area;
- restricting or controlling crossings and limiting access on haul roads;

- maintenance procedures for tyre changing;
- stopping truck operations in foggy conditions;
- modifying the failed batter slope;
- controlling and diverting drains which could affect batter stability prior to the monsoon period.

The follow up by the mine operator of recommended actions (high risk score items) was deemed commendable. A number of the lower ranked risk hazards remain and these will need to be addressed in future programs.

On-going Risk Management Programs.
The mine had decided that there should be a quarterly program for carrying out a hazard assessment at particular sites or functions in the mine. This program which is to be defined annually, should provide a great opportunity for continuous improvement in the mine.

Guidelines for Safety Management in Mines.
During the initial visit a Guideline to include Risk Management methods within a Safety Management System was developed. Vastan Mine decided that the Risk Management process should be the responsibility of the Safety Committee and hence would fit within the Safety Management System. The Vastan Mine had accumulated their safety information in a Safety Management Manual. This concept was incorporated in the Guideline and tested against mine management. The draft Guideline has been further refined in discussion in Udaipur, Dhanbad and in Australia.

Balaria Mine

This review took place only some three months after the initial visit. Because of this relatively short period, the review focussed on intent and commitment, and in addition, the process being followed. Three of the identified problem areas ie. strata control, dust control and noise control, were reviewed against the action plans earlier developed. An interview process using review sheets developed by mine personnel was employed. This process aimed to identify documentary evidence of the actions initiated or in its absence, verbal conformation of actions. It is normal in audits to insist on documentary evidence.

Standards, Guidelines and Systems
The review confirmed the development of the following standards:

- Stoping Strata Control Management Plan,;
- Dust hazard Control Plan;
- Occupational Health Management Plan;
- Prevention of Falling of person in the incline shaft;
- Prevention of Transformer fires.

While not yet been fully implemented, procedures have been put in place that will ensure their implementation and regular monitoring. It is of interest that the final two standards were mine initiatives following the initial visit, and are being introduced to the extent that equipment and facilities are available. The Review Team deemed the efforts of the mine in respect of these issues, commendable.

Team performance
Balaria mine management provided good support to those mine staff actively involved in implementing the program. The overall performance demonstrates the benefits that can be achieved by committed and trained staff in respect of safety management issues. For the benefit of other mines which can benefit from a consideration of similar programs, the Balaria team:

- demonstrated a high level of commitment to the process and to the principles underlying the establishment of safety management plans (including the planning for more and previously unidentified hazards);
- used a team approach with involvement of subordinate managers, safety and health officers;
- has had progress constrained only by lack of knowledge and availability of monitoring instruments;
- has the ability, with adequate support, to be a 'demonstration team' for portraying the value of the process;
- could benefit significantly from further training in dust sampling and dust allaying techniques;
- has the ability to, with further training, extend their capabilities to allow their value to the mine and the industry in respect of specific aspects of mine safety, to be more widely demonstrated.

3.6 Review/Audit of Model Mines 3 & 4.
3.7

This activity had not been conducted at the time of preparation of this paper. It is scheduled for completion in mid December 2001. AIMSTC believes that progress in the management of mine safety will be demonstrated.

4. Mine Emergency Planning.

As an additional and practical demonstration of the systems approach to mine safety, and which would constitute a residual component of the program – contributing to its sustainability, AIMSTC conducted simulated emergency response exercises at two mines, selected by DGMS as representative of mines in specific regions.

The program was delayed by a diaster of major proportions at the first selected mine, the Bagdigi mine in Bihar. With planning underway, and just a few weeks ahead of the simulated exercise, the mine was flooded as a consequence of miners 'holing through' into the flooded working of an adjacent abandoned mine, a number of miners lost their lives in the resulting inundation. Inquiries revealed that survey errors in the adjacent mine led Bagdigi miners to believe they were operating within adequate safety tolerances.

The first exercise was rescheduled and relocated to the Sijua colliery of TISCO and was concluded in May 2001. The second exercise was conducted at CIL's Western Coalfields Silewara Colliery in July 2001. Follow-up visits have been made to both mines to review their continuing performance.

The following notes relate to the Silewara Colliery exercise.

Assessment Procedures and Results
The exercise was planned and conducted in accordance with the 'Guidelines for the Conduct of Emergency Procedures Exercises' as established and utilised by the Queensland (Australia) Emergency Exercise Management Committee. The guidelines propose that exercises:

- be systematic;
- be consistent with the concept of mutual assistance from other mines;
- require direct reference to the risks at the mine;
- recognise that exercises should not necessarily be held on day shift;
- be inclusive of external agencies such as Mines rescue stations, police, media and senior company officials;
- have an audit and evaluation process;
- be subject to risk assessment principles to ensure the exercises do not introduce new safety risks to persons at the mine.

In recognition of these guidelines, the Silewara emergency exercise involved the following assessment and evaluation process:

- assessment documents were produced establishing the systematic initiation, control and assessment of the exercise;
- a scenario was developed strictly in accordance with the hazards present at Silewara Colliery;
- the Mines Rescue Brigade, senior company officials, DGMS officers, Workers Safety Officials and the ambulance service were involved;
- a total of 5 assessment teams comprising 21 persons were selected to evaluate and record the results of the exercise;
- de-briefings were conducted of all assessment teams to evaluate the results.

All assessment tools were developed against the internal standing orders of Silewara Colliery and in line with accepted practice for system audits.

While most persons involved in this exercise found their way to a place of safety, significant numbers of other persons did not. The potential exists for this number to increase significantly in the event of a real underground fire. It was apparent there had been a significant underestimation of the expected time required for persons to walk to their place of safety. Such a finding is not surprising and it is commonplace for the effect of poor visibility on walking speeds to be underestimated.

Of equal importance was the apparent lack of experience (and hence awareness) of the effects, consequences and extraordinary rates of propagation of heat and toxic gases that underground fires can generate. Such a lack of awareness may have lead to some degree of complacency with the persons involved in this evacuation exercise.

Results, Findings and Recommendations.
The main focus of the recommendations was to come up with improvements that are fiscally and technically viable for the Indian mining industry.

Major outcomes and opportunities for the improvement of the emergency preparedness and response systems at the Silewara Colliery include:

- All miners performed admirably in very difficult conditions and fully committed themselves to the exercise. The miners were extremely fit and handled the difficult egress conditions with no apparent difficulty.

- The nature of the fire and the type of rescue equipment available would have meant that in a real fire situation no one would have escaped from that section. Conveyor belt fires produce enormous amounts of smoke and toxic gases and with the limited ventilation available at this mine the smoke would not clear rapidly. Filter Self-Rescuers (FSR) were not suitable for the distances travelled in this mine. Under smoke conditions it is at least a two-hour walk out of the mine and FSRs have a realistic life of only 45 minutes. Oxygen self-rescuers would suffice if they were issued and caches were available to enable miners to complete the long walk out of the mine.

- The establishment of a refuge station underground would go a long way towards solving this problem. This station also needs to be equipped with a water supply and fail-safe communications with the surface, ideally through a borehole. An area of the mine was identified as suitable having an independent ventilation supply that could be used for this purpose. (Mine management indicated that the construction of a refuge chamber would go ahead with an objective of completion by December 2001).

- Rope guidelines should also be installed from the working faces to the refuge chamber to enable the miners to reach this safe haven. This type of system has been used with some success in Australia and is more effective than many high-tech electronic guidance devices. (Mine management will implement this recommendation).

- The assessor teams in some cases caused confusion and tried to direct the evacuation of the miners. The role of the assessors is to prevent injury and to log the actions of the escaping miners. Many of the miners would not have done as well as they did without the help of the assessors and some of their non-blindfolded supervisors.

- The fire fighting equipment and procedures were totally inadequate to fight a belt fire. The occurrence of a conveyor belt fire is not beyond the realms of possibility at Silewara Colliery and should be regarded as possible. Normal fire extinguishers are totally ineffective against this type of fire. Fire fighting training and equipment levels should be improved as a matter of urgency.

Regular exercises of this nature should be carried out and scenario-planning precursors to the exercises should also be carries out.

Gas monitoring was not carried out effectively during this exercise. The purchase of basic gas monitoring equipment should be investigated as a matter of urgency.

For the nature of the mining operation the alarm combination of telephone, whistles sirens and eucalyptus smell worked satisfactorily.

The exercise at the Silewara Colliery differed little from that conducted at Sijua Colliery and similar conclusions and recommendations were recorded. It is believed that these mines are typical of the industry and can be confidently referred to as industry indicators. To a large extent, Australian conditions, findings and recommendations were replicated here.

What has resulted from the carrying out of the two exercises and their subsequent follow-up is a blueprint for management action at all mines in India. DGMS are now equipped to cooperate with mines for all types in planning and executing evacuation or similar training exercises to equip mines for eventualities which, hopefully, may never arise.

From the Silewara Colliery, the lessons of this evacuation exercise can be applied much more generally. All mines should:

- Regularly test all aspects of the mine emergency system;
- Conduct simulated emergency response exercises with mine management responding pro-actively to this element of (underground coal) mining;
- Examine the adequacy of self-rescue equipment for the particular circumstances pertaining to the individual mine;
- Review the adequacy of (underground) fire fighting equipment for the likely fire situations;
- Ensure mine to surface communications are appropriate for emergency situations;
- Establish (independently ventilated) refuge chambers where underground conditions permit.

5. Conclusions and Acknowledgments.

This paper draws extensively on a series of individual reports prepared by AIMSTC specialists who have undertaken and directed the activities described in the paper. The activities described in some detail are those conducted in Year 4 of the project and which were designed to demonstrate the practical value of earlier 'groundwork'.

The vast scale of the industry has meant it was not possible in a program of this nature to directly influence mine operators at all levels and in all segments of the industry. By first training the mines inspectors, and in Year 4, by extending this training into typical operating mines, it is hoped to leave a residual skills base which will serve as a catalyst for an ongoing and increasing emphasis on mine safety.

The challenge is now with the industry in India. There is now a knowledge base and some practical examples of the benefits which result from a systems approach to safety management. To extend this broadly across the industry requires a commitment from the regulators, the operators and importantly, the unions and mineworkers. There is no reason why within some years India cannot challenge those countries employing more advanced mining technologies by recording a comparable safety record.

The contribution of the three shareholder companies of AIMSTC, and their key personnel, Robert Guy (Project Manager) of SCT International Pty Ltd, Stewart Bell (Deputy Project Manager) of SIMTARS, and Geo-Eng International Pty Ltd is acknowledged both for their input to the project and to this paper. The assistance of the Mines Inspectorates of the Australian states of Queensland, New South Wales and Victoria is also gratefully acknowledged.

DGMS Project Director Bhaskhar Battarcharjee and Project Managers, Rahul Guha and Ashim Sinha, have coordinated the Indian input to the project. The enthusiasm and commitment of Rahul Guha in particular should not go unacknowledged and his contribution to the paper and the project is now a matter of record.

AusAID, the Australian Government's International Aid Agency, sponsored and funded the (Australian component) of the project. Their support has been unequivocal and their commitment to ensuring that the project ethic survives the project formed the basis for the very productive Year 4 program. The support from both Canberra and New Delhi has greatly assisted the execution of the project. Their permission to publish this paper is appreciated.

ANNEX A

RISK ASSESSMENT EXAMPLE
conducted at Balaria Mine

Completed 6 April 2001

1. INTRODUCTION

This plan has been drawn up as an exercise to demonstrate the process of conducting a risk assessment and the method of deriving a plan to ameliorate the effects of the identified hazards.

Following a course on basic risk assessment principles the participants selected a hazardous area to assess and develop a plan to control the risks in this area, to an acceptable level.

The area chosen was the conveying of ore in the Balaria Mine of the Zawar Group of Mine of Hindustan Zinc Ltd. Potential hazards in this area were identified and assessed with regard to their risk.

This plan does not address a principal hazard but rather an area of activity of the mine. For the purpose of the exercise, this was deemed to be adequate to show the principles involved and how such a plan has to be drawn up.

The results of the exercise follow.

2. IDENTIFIED HAZARDS

Safety Definitions

Hazard: A source of potential harm or a situation with a potential to cause loss.

Principal Hazards: means a hazard with a potential to result in multiple fatalities.

Risk: The chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.

Prior to the exercise, a risk assessment course was held in order to bring all participants to the same level of understanding regarding the process and to reach a consensus regarding the use of the terms to be used in the assessment.

The risk assessment exercise was conducted on the selected area which included the production inclines, Phases One and Two. This area is from the bottom of the bottom of the bunker at 75MRL to 250 MRL, includes the transfer bunker, and from 250 MRL to 380 MRL on to the primary fine ore bin where transported ore is dumped.

The team consisted of a cross section of disciplines on the mine.

A hazard identification process was held using the principle that a hazard can also be defined as an unplanned or unwanted release of energy. The hazards were assessed in terms of risk, defined as the product of consequence, exposure and probability.

The values for the consequence of the hazard were based on the most reasonable worst case occurrence. Cognisance was given to controls already in place.

The results of the risk assessment are presented in Table A1.

Hazards with a risk of above 400 were deemed to require immediate action, those with a value below 400 but above 100 would be deemed to require attention, while those below 100 were acceptable, but required maintenance to keep them at this low level.

The controls for the groups of hazards were formulated accordingly. For hazards that require maintenance no controls were structured, as the present controls are considered sufficient.

For hazards requiring attention, controls for improvement were formulated and, for those controls that require immediate action, an action plan was drawn up.

Table A1: Risk Assessment results

	No.	HAZARD	Risk Assessment			
ENERGY			Consequence	Exposure	Probability	Risk Rating
Gravity	1	Fall of person.	15	5	7	525
"	2	Rolling/falling of stones & rocks.	10	5	3	150
"	3	Ore bouncing at loading/transfer points.	10	5	3	150
"	4	Belt rolling down after breaking.	10	5	3	150
"	5	Material striking person/systems after winch rope breakage.	20	3	2	120
"	6	Loosening ore in jammed chute.	10	3	3	90
"	7	Belt rolling down due to power failure.	5	5	2	50
"	8	Person falling from platform.	15	5	1	75
"	9	Falling tools, tackle, materials during maintenance.	10	5	3	150
"	10	Uncontrolled movement of belt reel while changing.	10	2.5	1	25
Mechanical	1	Loose parts caught between pinch points.	20	5	2	200
"	2	Rollers causing damage to belt.	5	5	2	50
"	3	Shaft failure, causing projectiles.	15	5	3	225
"	4	Breakage of rope of take-up winch.	15	5	1	75
"	5	Breakage of belt due to improper joints.	15	5	2	150
"	6	Sway of belt due to improper jointing.	5	5	2	50

Table A1
contd.

"	7	Improper shut-down procedure	40	5	1	200
"	8	Malfunctioning of sequence control.	5	5	1	25
"	9	Foreign materials damaging belt.	5	5	7	175
"	10	Uncontrolled movement of belt while jointing.	5	3	3	45
"	11	Slippage of tools/tackle.	10	5	7	350
"	12	Failure of lifting tackle while in use.	20	2.5	1	50
"	1	Electrocution.	20	5	3	300
Electrical	2	Fire due to short-circuiting.	10	5	2	100
"	3	Transformer/OCB fire.	40	5	2	400
"	4	Motor burns.	2	5	2	20
"	5	Failure of control devices.	5	5	7	175
"	1	Belt fire due to friction.	15	5	3	225
Heat Energy	2	Gear box heating.	15	5	3	225
"	3	Bursting of fluid coupling.	40	5	1	200
"	1	Bursting of air pipe.	15	5	3	225
Fluid & Air	2	Bursting of water pipe.	15	5	3	225
"	3	Bursting of fluid coupling.	40	5	1	200
"	1	Damage to hearing.	15	2.5	3	112.5
Other	2	Dust hazard.	50	10	7	3500
"						

ANNEX B **Project Postscript**

Information below has been added (September 2005) to indicate the ongoing level of serious accidents in the mining industry in India before and after the implementation of the Mine Safety Project. Data has been supplied by the Directorate General of Mines (from their records) at the request of, but has been interpreted by the author.

The information was requested to complement the presentation of the December 2001 paper at the Third Pacific Economic Cooperation Conference Minerals Network Meeting in Tiayuan, China in September 2005. Its inclusion was to permit a value judgement to be made about this technology transfer program and to determine if the positive impact associated with the program was reflected in ongoing mining accident rates. The program commenced in June1997, with the final Inspector training complete in Australia in May 1999. Upgraded mining regulations were progressively issued in the form of industry circulars and the DGMS internal training program was not established until the completion of project field activities in the third quarter of 2001. The Model Mine Program (Project Year 4 – July 2000 to June 2001) introduced new concepts of managing mining safety into the industry in a very limited way, being intended to act as a catalyst for the industry at large. It did not, and could not have far reaching implications in the short term.

Data below refers to the ten years, 1994 to 2004 for which serious accident and production statistics were made available by DGMS. The project took place in Years 4 to 8 (1997 to 2001), partway through the reporting period.

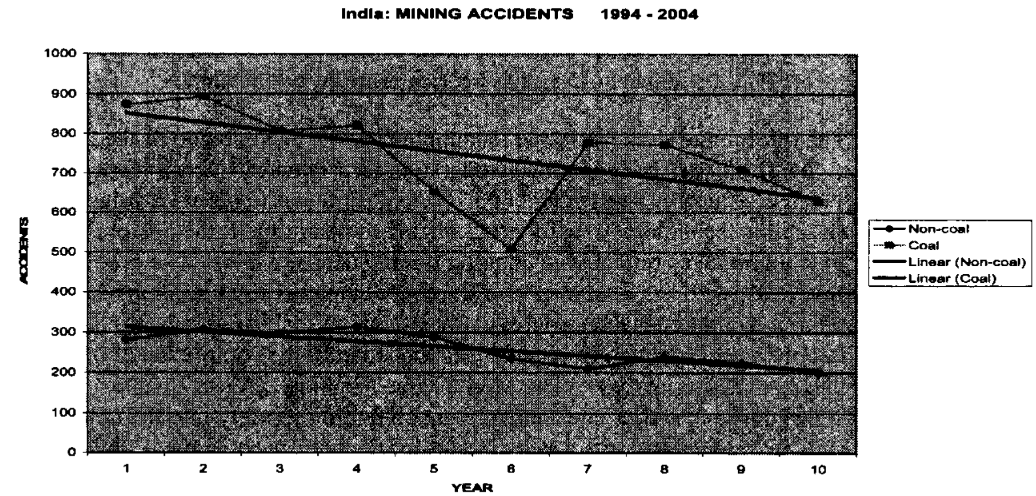
Information relating to the incidence of serious accidents for the coal and the non-coal sectors has been tabulated with this data being used to calculate accident rates in relation to production – a common international determinant of safety performance.

Table B.1 Number of Serious Accidents in Indian Mines - 1994 to 2004.

		Non-Coal				Coal		
Year		**Fatal**	**Serious**	**Total**		**Fatal**	**Serious**	**Total**
1994	1	57	225	282		156	717	873
1995	2	58	250	308		137	757	894
1996	3	63	235	298		131	677	808
1997	4	68	246	314		143	677	820
1998	5	54	234	288		131	522	653
1999	6	60	174	234		132	376	508
2000	7	50	160	210		117	661	778
2001	8	62	178	240		105	667	772
2002	9	50	174	224		81	629	710
2003	10	54	147	201		83	546	629
2004	11	47	119	166		83	343	426

Despite a significant increase in the accident level in the year 2000, the overall trend is one of continuous improvement over the ten year period. The coal industry has recorded an average decrease of the order of 5% per annum and the non-coal industry around 4%. Chart B.2 below clearly indicates the longer term trends. What is clear is that despite individual year variations, the trend already established pre-project continues through the life of the project and beyond. It cannot be established convincingly that the implementation of this specific project had a visible impact on industry accident rates, performance improvements being possibly due to factors already in train.

Chart B.2 India Mining Accidents 1994 to 2004



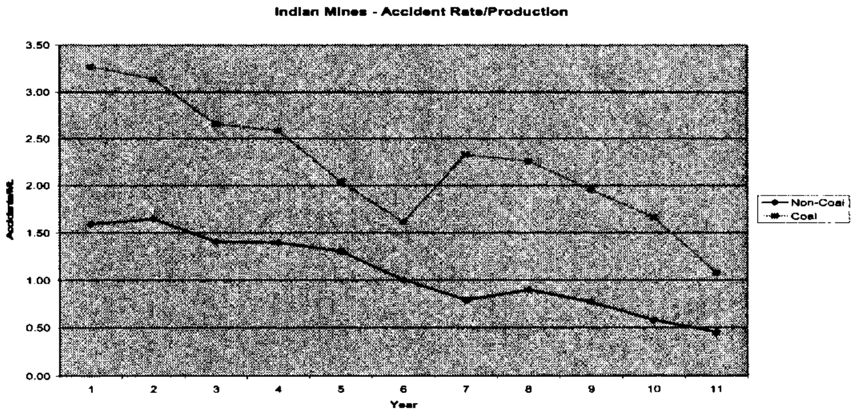
However, absolute figures of accidents do not reflect the level of activity within the industry in a reporting period. For comparative purposes, and international comparisons are available, relating the incidence of accident occurrence to the concurrent level of production provides a more accurate picture of ongoing industry performance. Table B.3 below sets out for the same period as above, the level of accident occurrence per million tonnes of production in both the coal and non-coal sectors.

Table B.3 India: Serious Accidents per Mt. of Production.

		Non-Coal				**Coal**		
Year		Serious Accidents	Production Mt.	Accidents/Mt.		Serious Accidents	Production Mt.	Accidents/Mt.
1994	1	282	177	1.59		873	267	3.27
1995	2	308	187	1.65		894	285	3.14
1996	3	298	212	1.41		808	304	2.66
1997	4	314	225	1.40		820	317	2.59
1998	5	288	221	1.30		653	320	2.04
1999	6	234	233	1.00		508	315	1.61
2000	7	210	265	0.79		778	334	2.33
2001	8	240	267	0.90		772	342	2.26
2002	9	224	291	0.77		710	363	1.96
2003	10	201	347	0.58		629	379	1.66
2004	E	166	366	0.45	E	426	395	1.08

Decreases in the incidence of accidents of the order of two thirds over this ten year period are observed for both industry sectors. This is more clearly illustrated in Chart B.4 below.

Chart B.4 Indian Mines: Accident Rate with respect to Production - 1994 to 2004.



While Table B.5 below is not directly comparable with figures for serious accidents presented above, in that it relates the fatality rate to production levels for coal mines, it demonstrates the progress being made in India in the reduction of the incidence of coal mine fatalities. However it also demonstrates that in comparison to the 'developed' countries of U.S.A and Australia, fatality rates are too high and continuing attention to reducing these is mandatory. India, with the assistance of Australia has demonstrated a commitment to this objective.

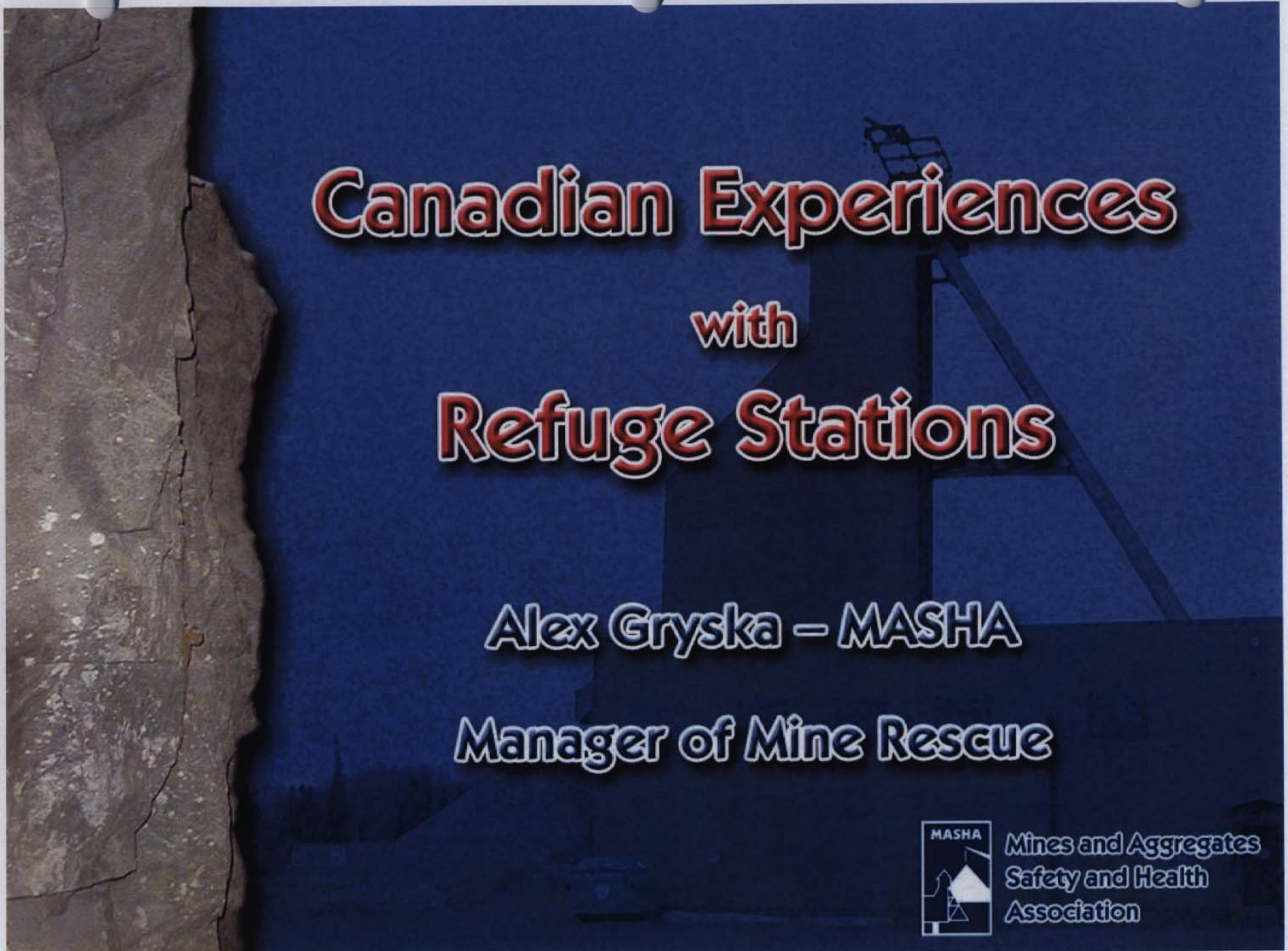
Table B.5 Comparison of Coal Mines Fatality Rates in other Countries (1994 to 1998).

	Fatality Rate per million tonnes of coal mined						
Year	India	Czech Rep.	Japan	West Germany	U.K.	U.S.A.	Australia
1994	0.90	0.12	0.14	0.29	0.05 (1992).	0.04	0.02
1995	0.77	0.26	0.32	0.26	N.A.	0.05	0.02
1996	0.48	0.15	0.00	0.25	N.A.	0.04	0.04
1997	0.52	0.23	0.47	0.19	N.A.	0.03	0.02
1998	0.47	0.13	N.A.	N.A.	N.A.	N.A.	N.A.

It is still unclear how the influence of the India: Mine Safety Training Project is reflected in the safety performance of the Indian mining industry. All the indicators are that India is coming to terms with a problem long recognized as of major concern to the industry and the country, and that the initiatives being taken, the procedures being put in place and the emphasis on safety as a mine operator responsibility are all contributing factors in the documented improvement. The extent to which the technology transfer program has contributed is a matter of conjecture but those associated closely with the program believe strongly that it contributed to the safety ethic being identified as being of prime importance in achieving production targets, and lessening the incidence of accidents.

Countries with less than acceptable mine safety records can learn from the techniques employed and the program objectives which emphasize the role of every individual mine worker as responsible for his (and his workmate's) safety. The basic concept inherent in every Safety Management System is to recognize, and eliminate or minimize those hazards conducive to accidents, prior to that situation being recorded as the cause of a serious accident, perhaps one having fatal consequences.

DOCUMENT 5


Canadian Experiences
with
Refuge Stations
Alex Gryska – MASHA
Manager of Mine Rescue
MASHA
Mines and Aggregates
Safety and Health
Association

Lessons Learned

- 1928 Hollinger mine fire
- 39 miners lost their lives
- refuge stations first established

Legislated Requirements

Section 26

Where the procedure in case of a fire in an underground mine provides for the for the use of refuge station for workers, the refuge station shall;

- (a) Be constructed with materials having at least a one-hour fire-resistance rating;
- (b) Be of sufficient size to accommodate the workers to be assembled therein;
- (c) Be capable of being sealed to prevent the entry of gases;
- (d) Have a means of voice communication with the surface; and
- (e) Be equipped with a means for the supply of,
  - (a) Compressed air, and
  - (b) Potable water.

MASHA

Refuge Station Equipment, Furnishings and Supplies

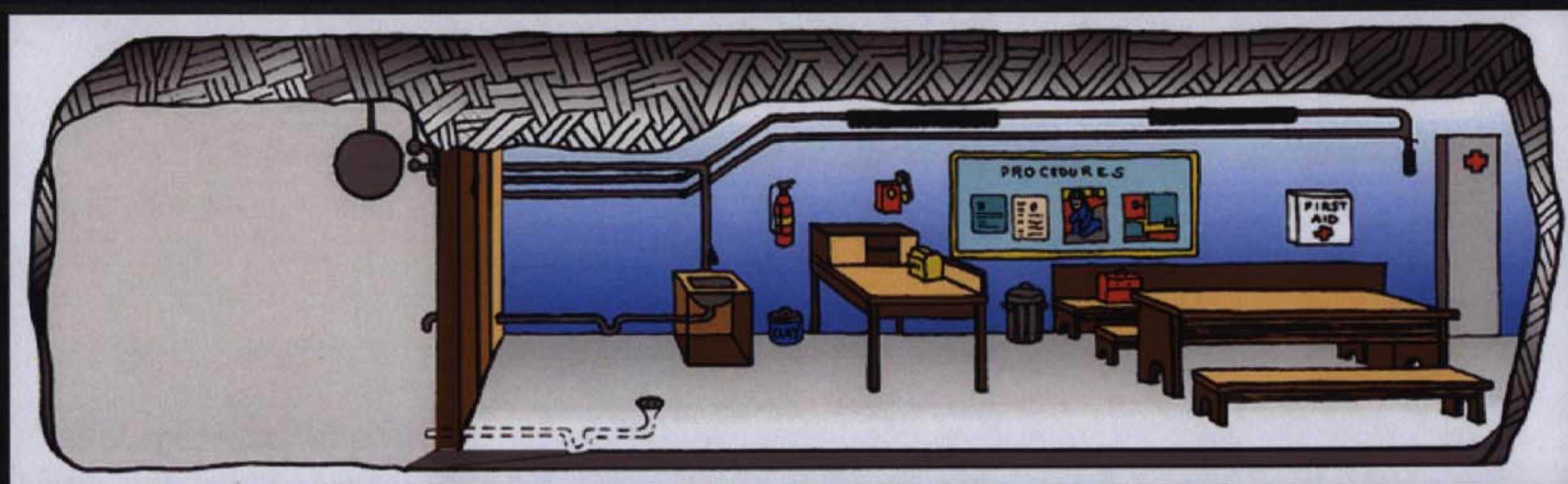
- Air line
- Potable water
- Fire/sealing clay
- Communication system
- Lighting
- Seating
- Emergency equipment
- Miscellaneous supplies

MASHA

Types of Refuge Station at Ontario Mines

- Permanent with compressed airlines.
- Permanent with RANA (Rimer Alco North America) System.
- Portable stations with cascade air cylinders.

Idealized Schematic
Single Door Refuge Station



MASHA

Idealized Schematic
Double Door Refuge Station

MASHA

Sequence of Refuge Station

Underground refuge station outside entrance – steel door and cement wall, p-trap through wall and floor

MASHA

Underground refuge station – inside of door way, hot water tank on right, sink and potable water on left

Underground refuge station – inside facilities: food warming oven, microwave, fridge, potable water fountain, sink

MASHA

Underground refuge station notice board containing diesel ventilation charts and fire orders for level

MASHA

Underground refuge station- stretcher box, eyewash station and emergency list of occupants (name, badge #, supervisor)

Underground refuge station – telephone list for all of mine, telephone

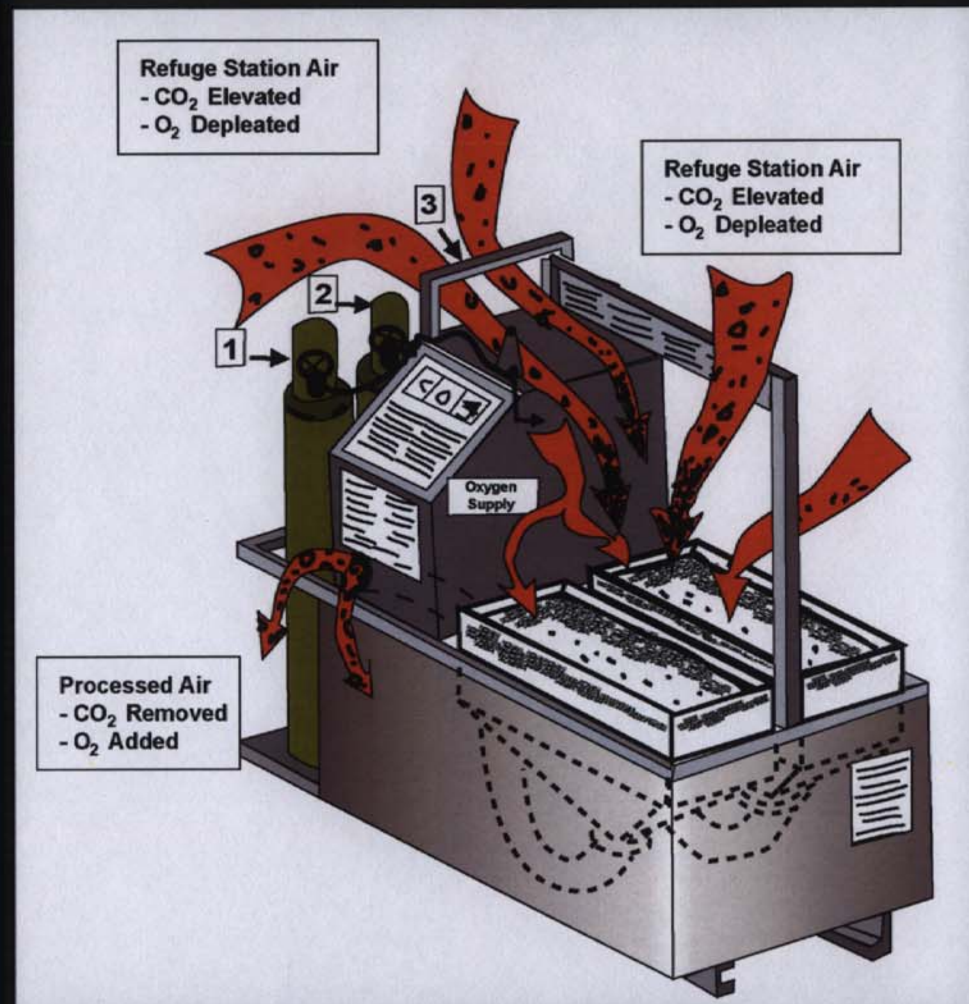
Underground refuge station fire clay in pails. Used to seal doorway.

Underground refuge station air and water lines plumbed inside refuge station. Air line is plumbed with silencer and cracked open to allow stench to reach occupants at any time.

Underground refuge station showing tables and benches for occupants

MASHA

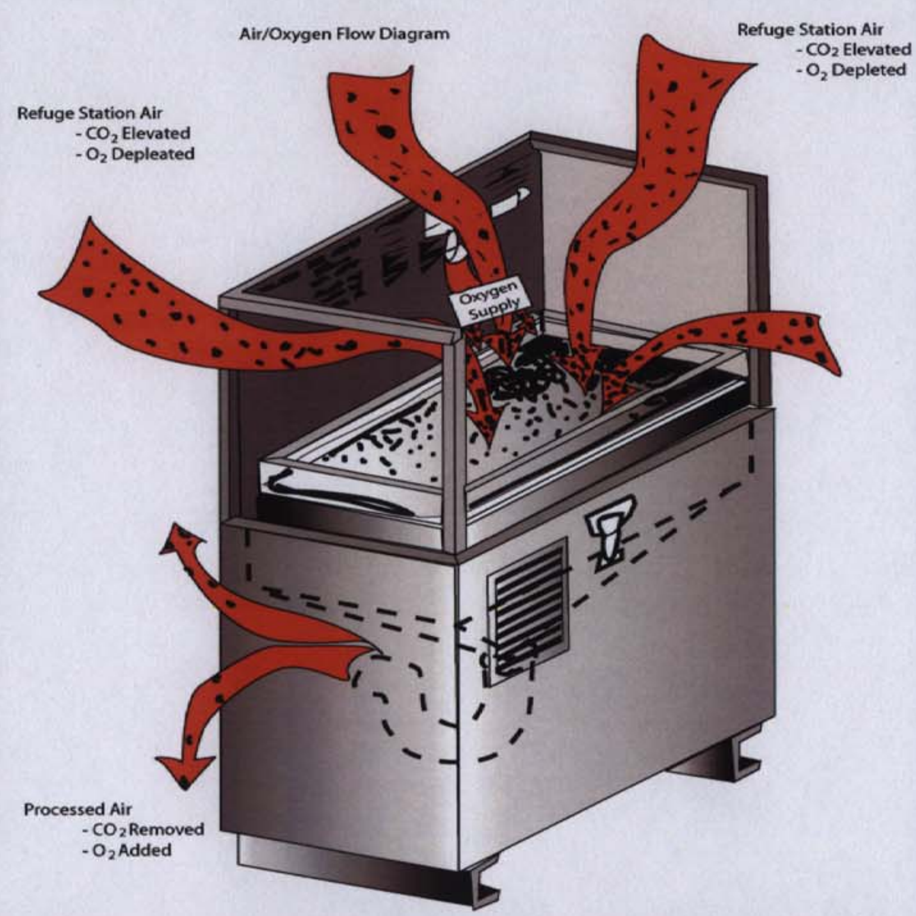
Refuge One System Diagram



MASHA

Refuge One System Diagram

"REFUGE ONE" AIR CENTRE



Refuge Station Procedures

- Person to take control
- If air line available, crack header lightly
- If using bottled air use sparingly
- Record names of personnel
- Follow site emergency procedures

Conclusions

- Need to establish a mine emergency preparedness plan.
- Train workers in proper procedures.
- Evaluate the system and procedures by conducting audits, drills and simulations.
- Modify the plan to accommodate changes in technology and as mining advances.

MASHA

Thank you

ANY QUESTIONS ?

MASHA

DOCUMENT 6

Coal Mine Refuge Chambers
Design Concept & Provisions

Mine Escape Planning and Emergency Shelters Workshop
National Academy of Sciences
Washington, DC
April 18, 2006

Mark Skiles, Director
Kelvin Wu, Ph.D., P.E.
Richard Allwes, P.E.
Terence Taylor, P.E.
MSHA Technical Support

Refuge Chamber Overview

- Critical Element of Emergency Response Plan
- Should be located within 1,500 feet of work areas in the mine or otherwise based on model studies to determine the appropriate locations.
  - Distance based on low/zero visibility, 50% supply of a 60-minute SCSR, entry height, and the respiratory rate of a miner walking under duress
  - Further reduction for entry heights less than 5 feet
- Provide a minimum of 72 hours of safe refuge to hazards caused by mine fires, inundation of water and noxious gases, and entrapment
- Types
  - Permanent
  - Temporary
  - Portable

Refuge Chamber
Travel Time and Distance Considerations

- Disorientation/indecision
- Visibility
- Miner weight & condition
- Anxiety level
- Entry height
- Debris in entries

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

Actual Duration of SCSR's, 1997 ACARP Project- Number C5039

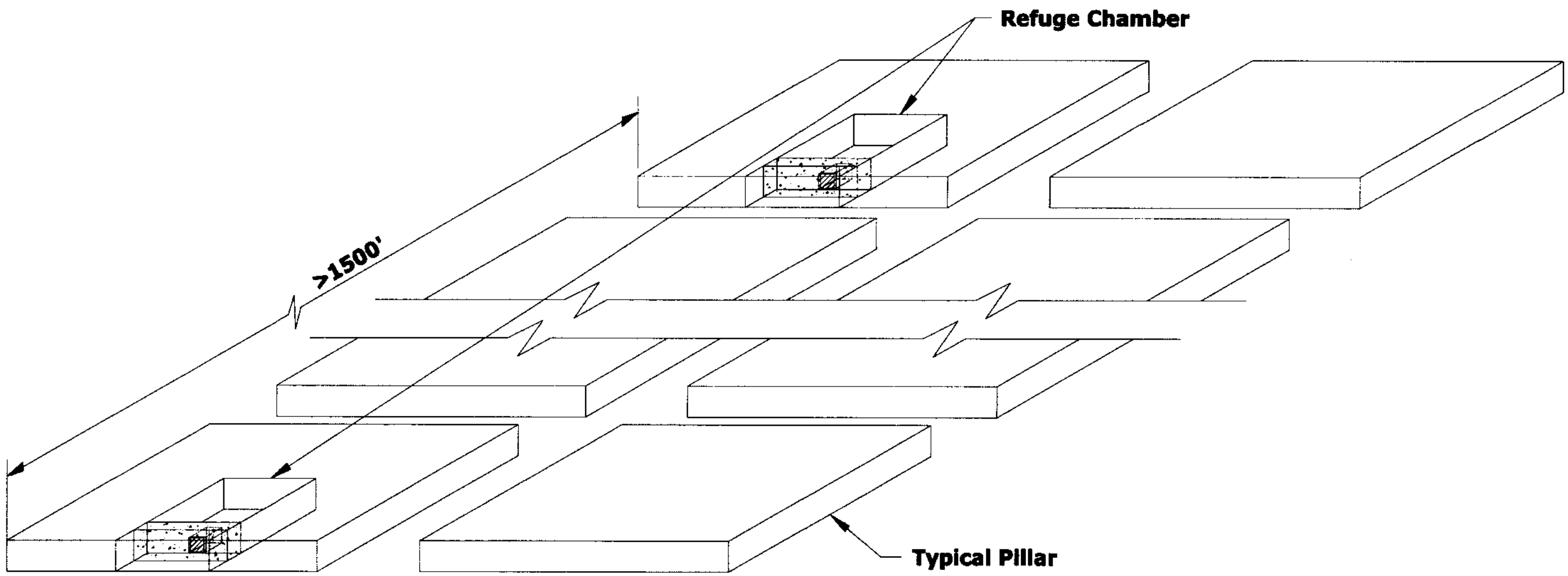
Chamber Types

- Permanent Chambers would be installed in main travel and escapeways. Permanent borehole would be provided for continuous air supply and communications.

- Temporary Chambers would be installed in active areas. Oxygen tanks would be provided for a temporary air supply. When the areas are no longer active, the water/air-tight doors could be removed and re-used for construction of other temporary chambers.

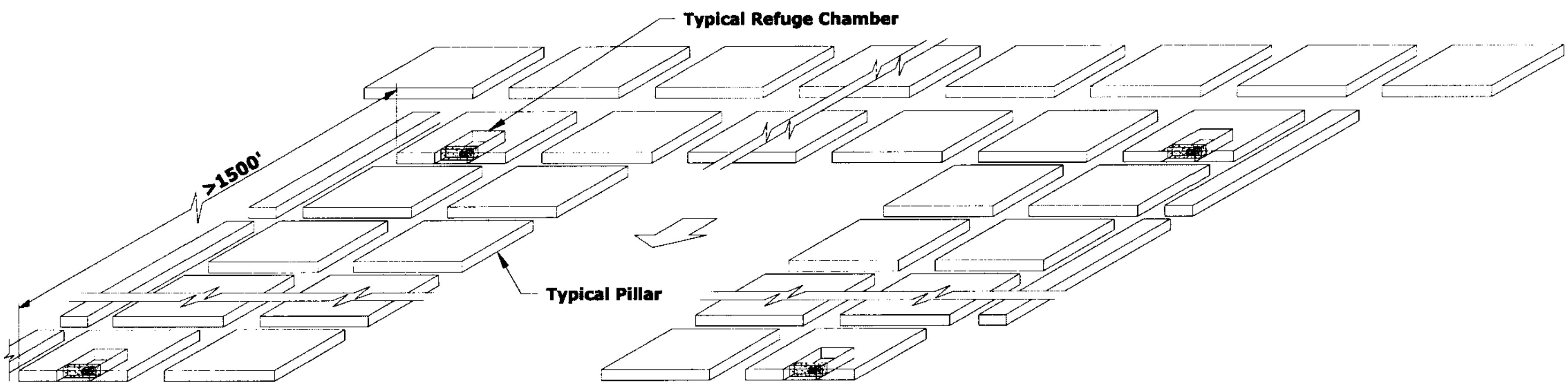
- Portable Chambers would be located in active areas and would be moved to new areas as the mining progresses. Chambers are not considered explosion or inundation resistant and rely on oxygen tanks rather than a borehole for air supply.

Permanent Refuge Chamber for Room & Pillar Operation



Room and Pillar Mine Refuge Chamber
General Arrangement
(Isometric View)

Temporary Refuge Chamber for Longwall Operation



Longwall Mine Refuge Chamber
General Arrangement
(Isometric View)

Refuge Chamber Provisions

- Life Support System in the Chamber:
  - Air supply:
    - Medical-grade oxygen in bottles
      - 72-hour minimum duration for full complement of personnel
      - Consumption rate is 0.5 liters per minute per person
    - Fresh oil-free air source from surface through a cased borehole
  - Scrubbers for carbon monoxide and carbon dioxide
  - Humidity control
  - Temperature control
  - Water & Food

Refuge Chamber Provisions (continued)

- Cased borehole:
  - Surface to refuge chamber
  - Fresh air supply
  - Maintain positive pressure in refuge chamber
  - Communication/electric lines
- First aid supplies
- Lights
- Power supply
- Sanitation facility
- Seating & table
- Stretcher

Coal Refuge Chamber Requirements 30 CFR 75.1500

- Secretary may prescribe
- Properly sealed and ventilated
- Suitable locations in the mine for people to go for protection against hazards

Coal Refuge Chamber Requirements 30 CFR 75.1500 (continued)

Provisions:

- First aid materials
- Adequate supply of air and self-contained breathing equipment
- Independent communication to surface
- Proper accommodations for persons awaiting rescue
- Such other equipment Secretary may require

- Plan for erection, maintenance, and revisions to chamber
- Training of miners in their proper use

M/NM Refuge Chamber Requirements 30 CFR 57.11052

- Fire-resistant construction
- Accommodate normal number of persons in particular area of mine
- Gastight
- Provisions:
  - Compressed air line
  - Waterline
  - Suitable hand tools
  - Stopping materials

Compressed Air Line Issues

- Mine fire may vaporize rubber seals of victaulic couplings of air line
- Explosion may rupture air line
- Two incidences occurred in Ontario and Manitoba, Canada
  - Fire drew air from refuge chamber due to compromised air line seals
  - Ruptured air line transported smoke and noxious fumes into refuge chamber

Permanent Refuge Chamber

- Cut a stub entry (or dead end) into the coal and close the opening with a bulkhead, equipped with a water/air-tight door.
- Or close-off a cross-cut or entry by installing 2 bulkheads, equipped with water/air-tight doors
- This type of station should be strategically located and large enough to accommodate all miners in an area

Permanent Refuge Chamber Design Requirements

- Resist an explosion with a minimum 80-psi overpressure and impact from projectiles such as cribs, roof fall material, etc…
- If an inundation hazard exists, the chamber should also be able to resist a minimum of 100 feet of water head
- Able to survive initial and secondary explosions
- Concrete design codes:
  - ACI 318 – for explosion
  - ACI 350 – for water inundation

Permanent Refuge Chamber Design Requirements (continued)

- Foundation investigation
- Keyed into strata 2-feet minimum
- Anchored/dowelled into the surrounding strata
- Grout curtain around the perimeter of the bulkhead:
  - Consolidate/strengthen coal measure strata
  - Reduce permeability
- Mine roof should be extensively bolted both inby and outby the chamber

Permanent Refuge Chamber Design Requirements (continued)

- Other supplement roof supports should be provided near the bulkhead
- Equipped with an air and watertight, fire-rated steel door – 3’ diameter or 3’ wide by 3’ high
  - Minimum dimension for stretcher or mine rescue personnel in full apparatus
- Fire rated – (Shotcrete entrance for fire protection)
- Rock Anchors:
  - Anchor the foundation
  - Reinforce the coal measure strata

Permanent Refuge Chamber Design Requirements (continued)

- Construction plans and specifications
- Material specifications
- The plans and specifications should be prepared and certified by a registered Professional Engineer and made available to MSHA for review and comment prior to construction
- Material tests during construction according to applicable ASTM standards
- Inspection by an independent contractor or MSHA personnel during construction for quality control

Permanent Refuge Chamber
RC Bulkhead Design

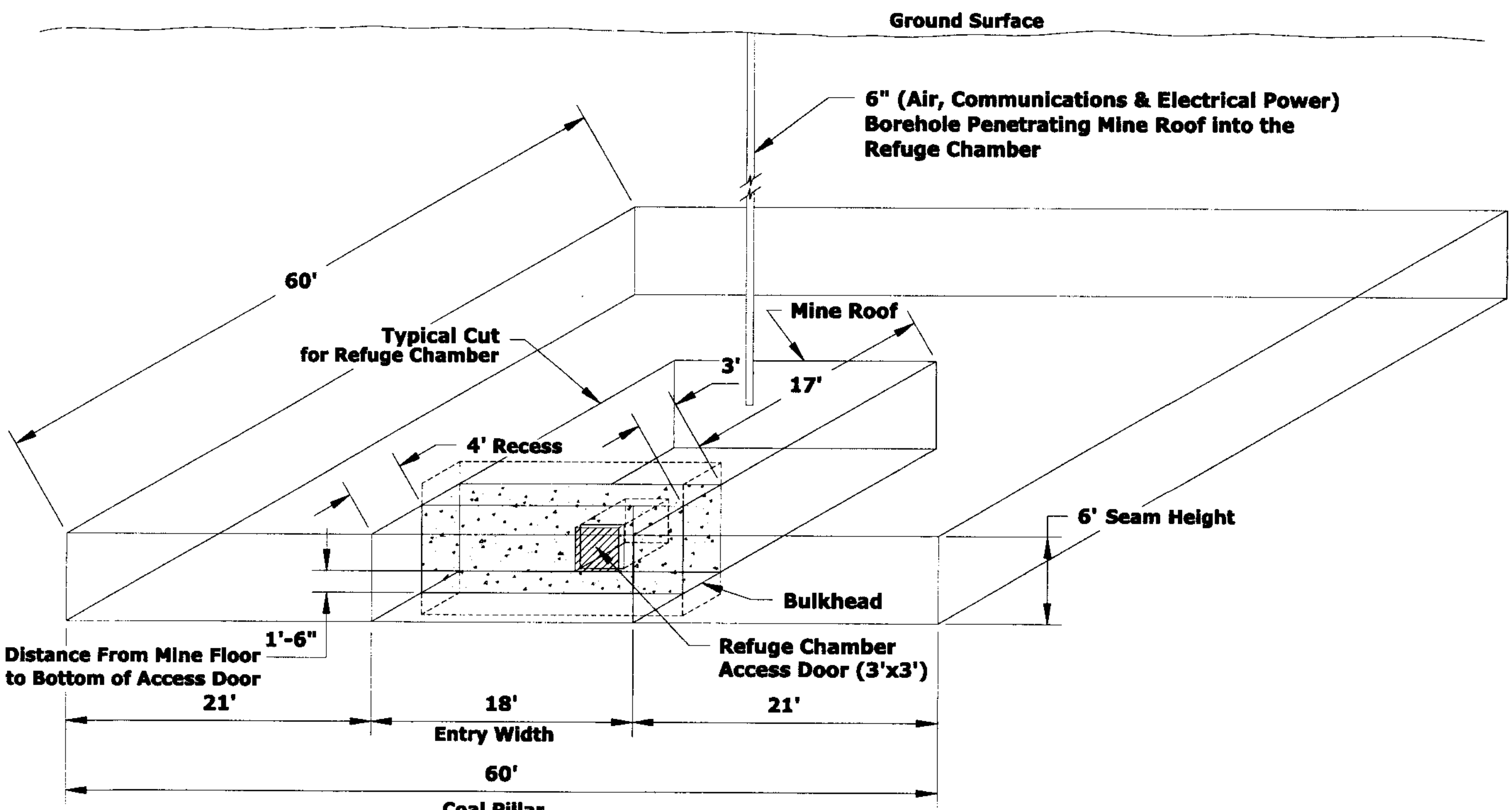
Concrete Design

- 20-ft wide x 7-ft high stub entry opening
- 3-ft thick wall for 80 psi static pressure and 100 foot hydrostatic water head

Foundation Design

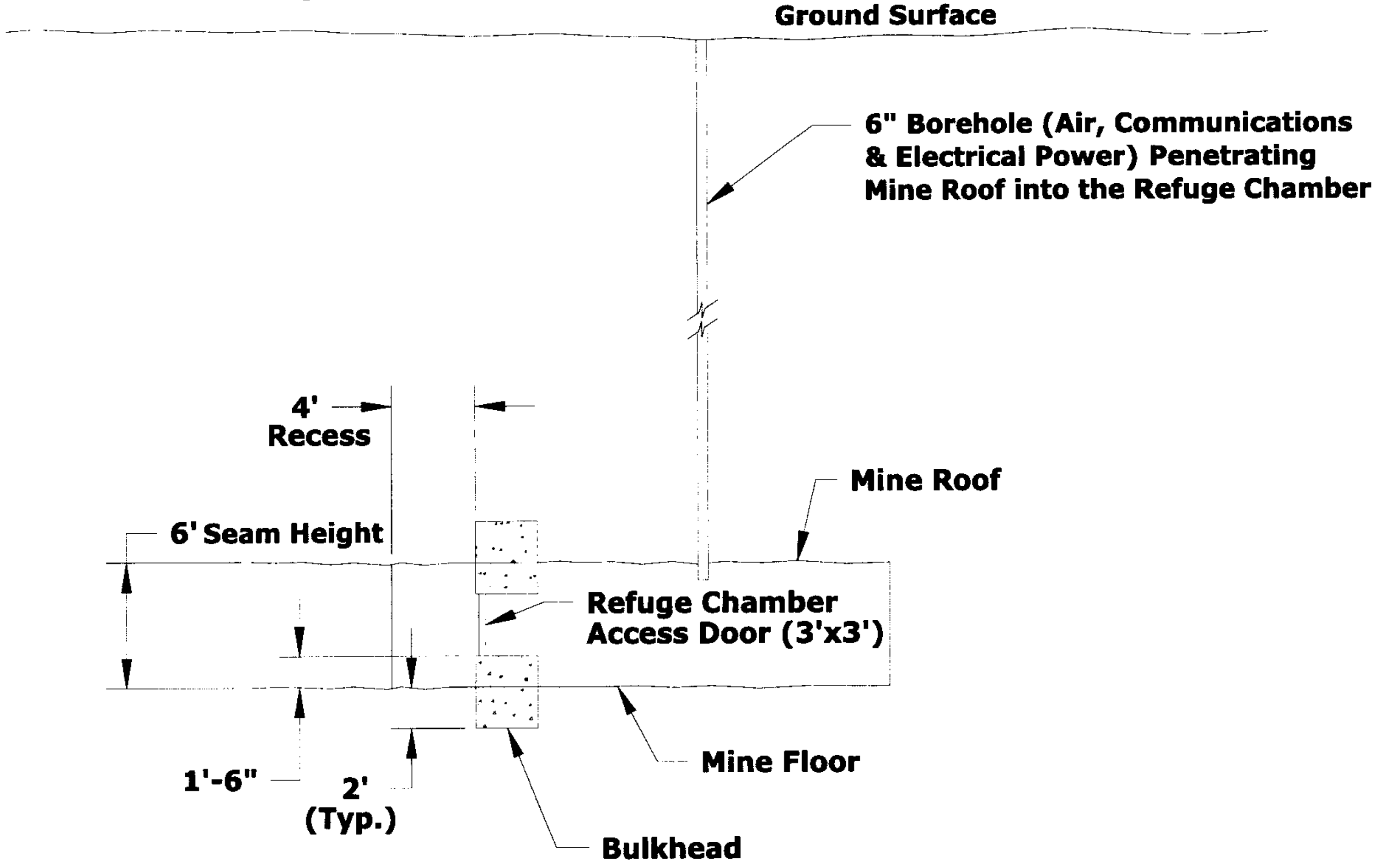
- Multiple wedge failure analysis
- Seepage

Permanent Refuge Chamber



Refuge Chamber
(Isometric View)

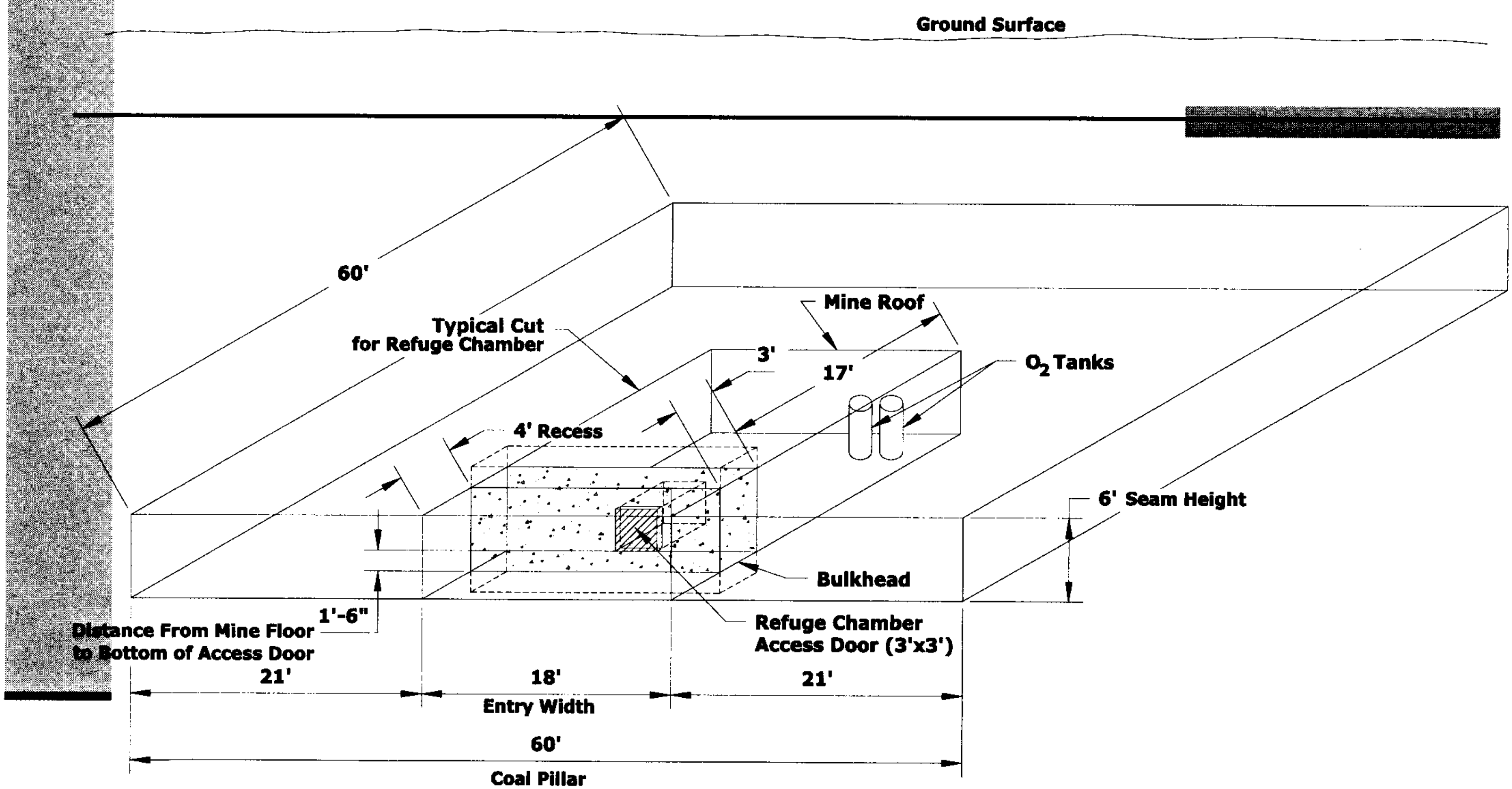
Permanent Refuge Chamber



Cross-Section through Bulkhead (Elevation)

FOR REFERENCE ONLY
NOT TO SCALE

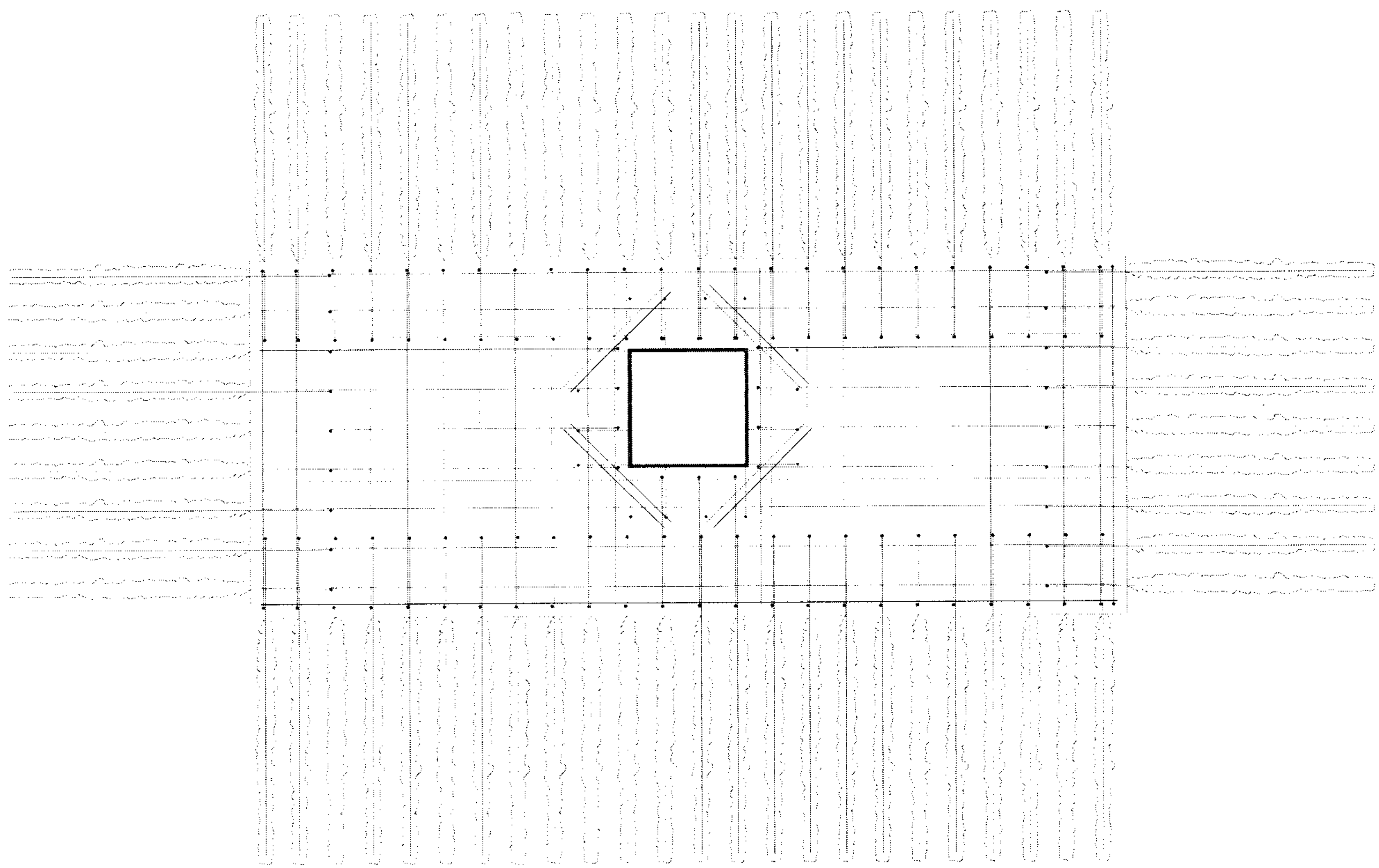
Temporary Refuge Chamber



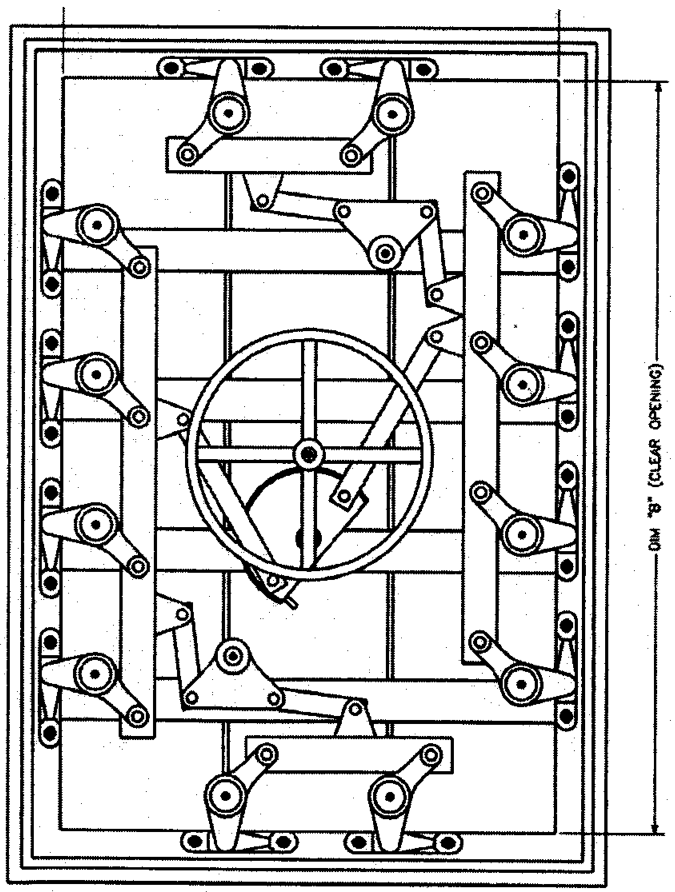
Temporary Refuge Chamber w/O_2 Tanks
(Isometric View)

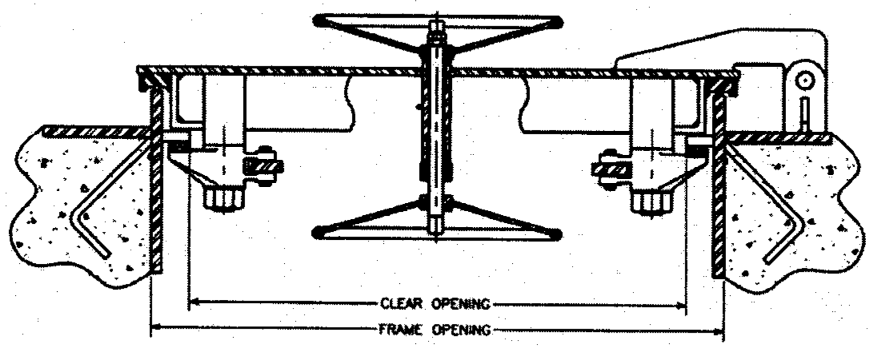
Permanent Refuge Chamber

RC Bulkhead Design (Steel Layout)



Permanent Refuge Chamber Watertight Door

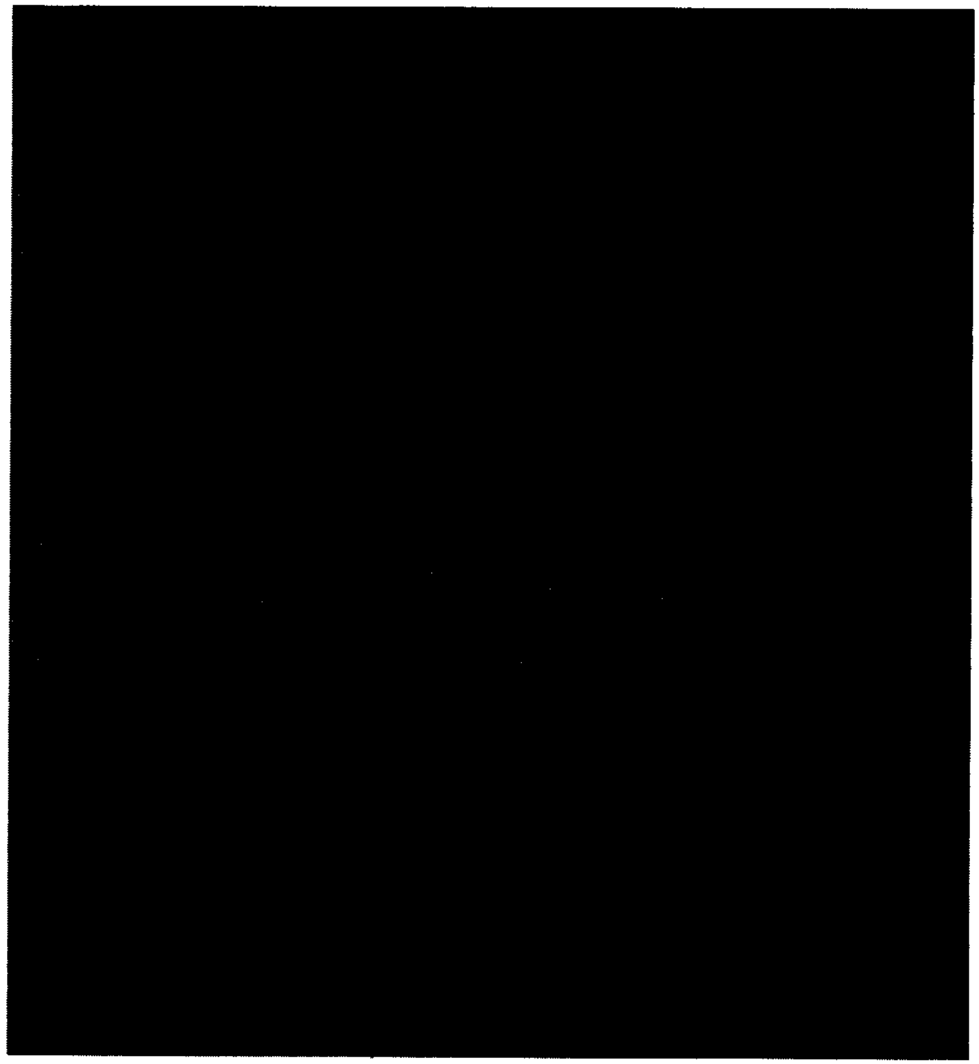




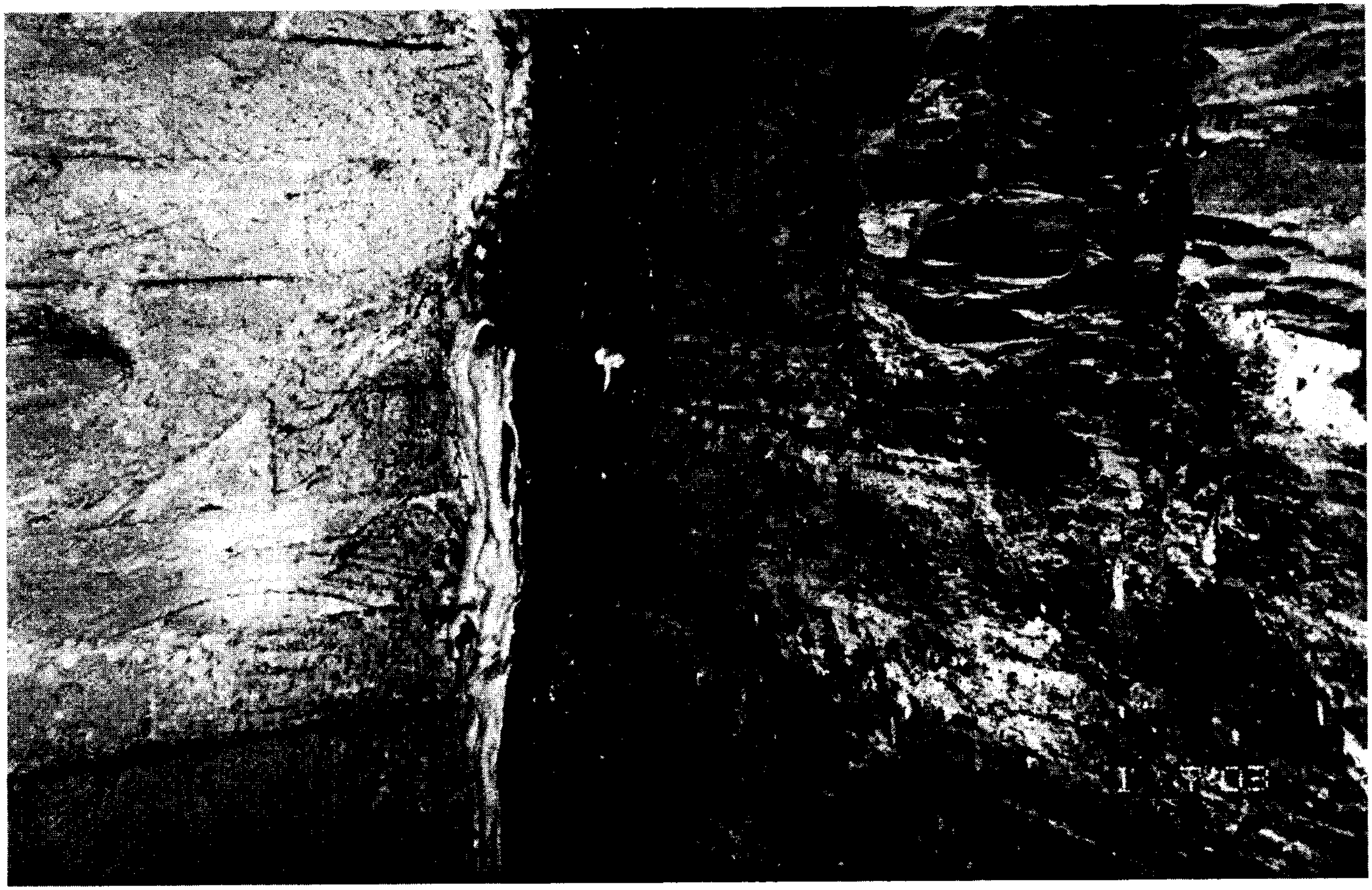
TYPICAL JAMB SECTION
SHOWN EMBEDDED

Roof Dowels for Anchorage

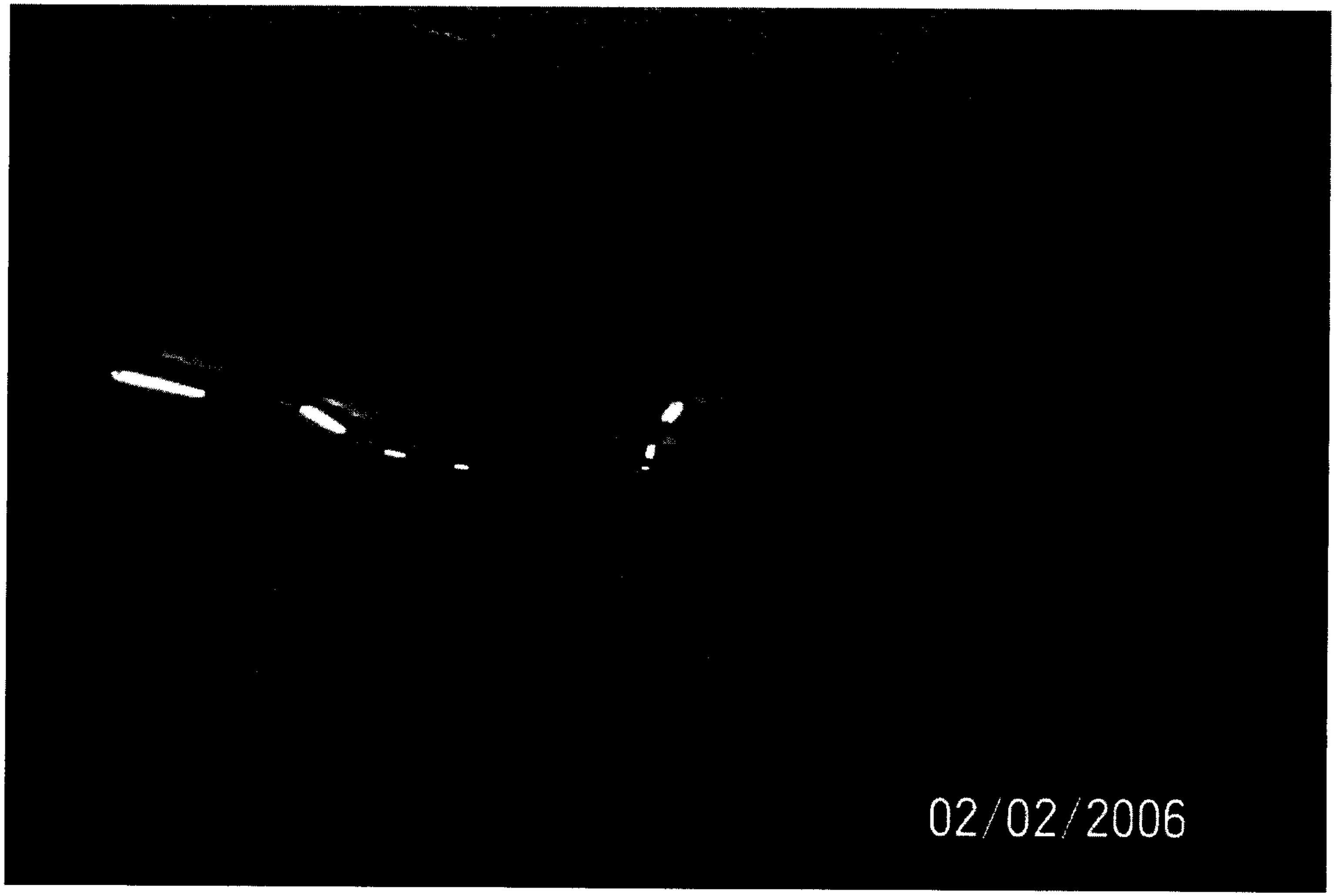
Rib and Floor Hitching



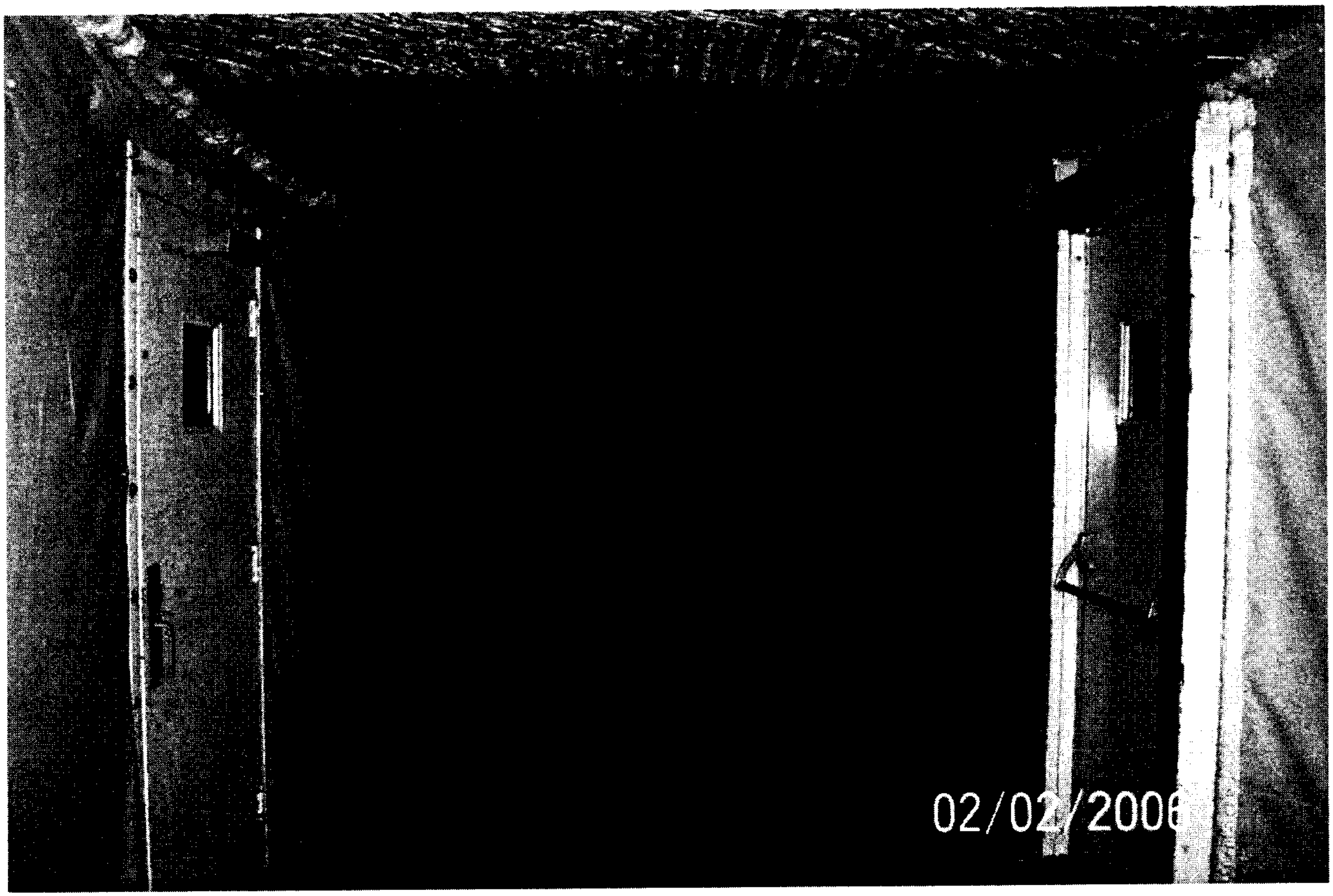
Contact Grouting



The Mosaic Company
Potash Operations, Canada
General View of (Non-Structural) Permanent Refuge Station



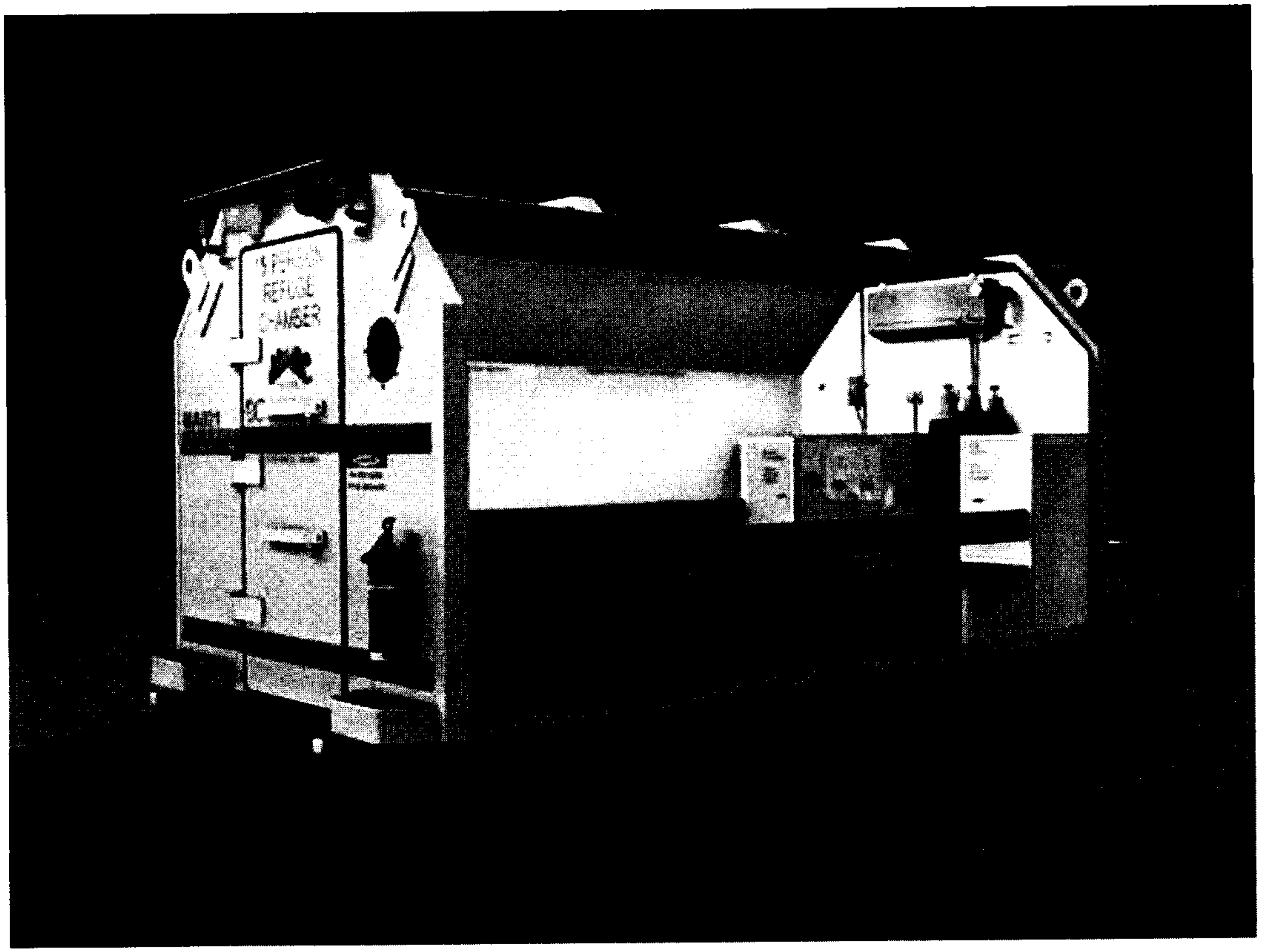
The Mosaic Company
Potash Operations, Canada
View of (Non-Structural) Airlock at Entrance



Portable Refuge Chambers

- Portable steel or fiberglass enclosures are provided for remote areas in the mine near active work areas
- Capacity - up to 20 miners
- Generally equipped with compressed air or oxygen and a carbon dioxide absorbent to compensate for limited air content
- Cost ranges between $45,000 to $100,000 depending on the manufacturer and features
- The portable chambers are not designed to withstand explosion pressures.

Mine Arc Systems - Portable Chamber

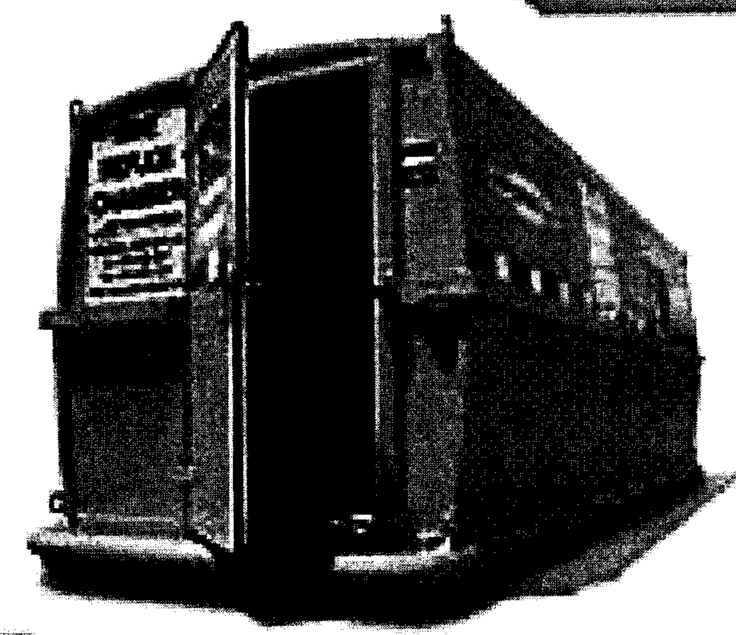


Mine Arc Systems - Portable Chamber

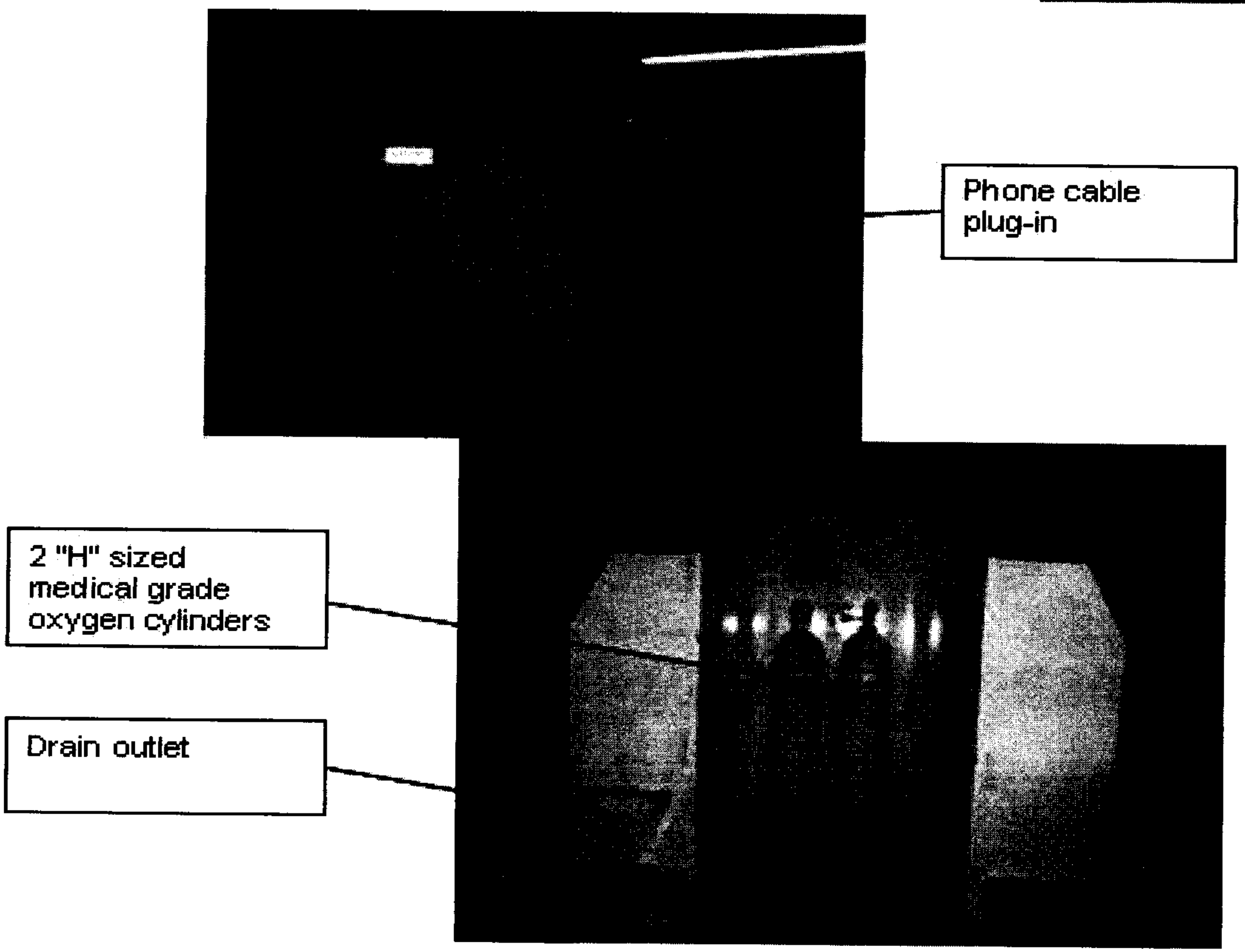
- Capacity: 8 - 20 people
- Air Systems
  - Filtered and Silenced Compressed Mine Air
  - Oxygen Cylinders
    - 15 people/15 hours
  - Oxygen Candle
    - 15 people/5 hours
- Electrical System
  - Air Conditioning
  - Lighting System
    - 40-hour battery life
- Airtight Door
- Escape Hatch
- Utilities
  - Seating
  - Storage
    - Moisture Absorbent Desiccant
    - Water
    - Scrubbers for carbon monoxide & carbon dioxide
    - First Aid Kit
    - Blankets
    - Oxygen Candles
    - Tools
  - Self Contained Toilet

Shairzal Safety Engineering, Australia Mine Refuge and Fresh Air Bases

- Capacity: 20 people
- 40+ Hours Back Up Refresh Air Scrubber, Toxic Gas Removal
- Airlock On Entry — Self Closing Door with Windows
- Internal optional equipment:
  - Lighting
  - Toilet
  - Chemical breathing apparatus
  - First aid kit
  - Phone

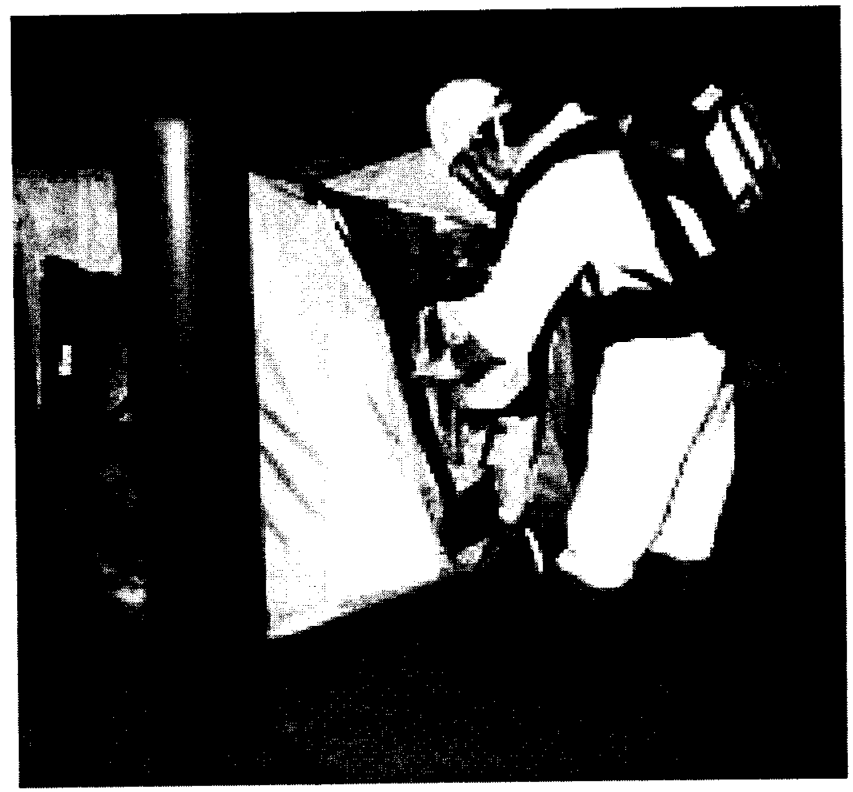


Portable Refuge Stations Colonsay Potash Mine, Canada



Strata Products USA
Portable Inflatable Chamber

- Capacity: 5 – 15 miners
- Air lock entrance
- Stowed in a durable carry bag
- Single person operation
- Entire unit inflates in minutes
- May use oxygen candles and chemical carbon dioxide scrubbers



Any questions?

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DOCUMENT 7

Criteria for the design of emergency refuge stations for an underground metal mine

By D J Brake[1], Fellow and G P Bates[2]

INTRODUCTION

The rationale for the design of the Emergency Egress (escape and entrapment) strategy for one underground metal mine has been previously described (Brake, 1999). Two of the key conclusions for this mine, which is equipped with 30 minute oxygen-generating self-contained self-rescuers (SCSR), were the need to ensure no person is ever more than 750 m from an emergency refuge station (ERS) and that it could take up to eight hours to rescue workers from underground[†]. These conclusions were based on a number of considerations including the non-availability of a credible, 'personal' entrapment procedure at the workplace, the duration of self-contained self-rescuers when used for travel, the need for rapid 'clearing' of mine personnel to effectively and safely target mine search and rescue resources and the maximum time to either put a fire out, or to rescue affected personnel. As there is no Australian standard for refuge stations[‡] (or for self-rescuers), this paper follows with guidelines for the location and specification of both fixed (permanent) and relocatable Emergency Refuge Stations (ERSs) that may be applicable to other underground Australian metal mines.

CONCEPT OF FIXED EMERGENCY REFUGE STATIONS AND RELOCATABLE EMERGENCY REFUGE STATIONS

Whilst it was deemed essential to have sufficient relocatable ERSs to meet the distance requirement above, it was also recognised that it was essential to ensure the underground 'cribrooms' (lunch rooms) were also set up as ERSs. This is for three reasons:

- A fire could credibly occur while workers are on meal break, eg brakes and tyres catch fire on a hot, parked, diesel LHD unit.
- In an emergency situation, workers may travel past a relocatable ERS to the cribroom, either because of panic, or because it is already 'full' or because there is no smoke around and they want to go to a familiar assembly point.
- Newly 'inducted' workers in the mine will not be familiar with the location of and travel routes to *all* ERSs from their first day; however, there is a much higher likelihood that they will know where the lunch room is.

Therefore it was considered essential, in effect, to have relocatable ERSs in the working areas, backed up by cribrooms which were also set up as refuge stations. Under these location criteria, there will obviously be multiple options for any person needing to escape from a fire and 'redundant' egress and entrapment capacity.

LOCATION OF RELOCATABLE ERSs

The *minimum* number and placement of Emergency refuge stations is based on the higher of two criteria:

- the number to meet the requirement that no mine worker be more than 750 m from an ERS at any time; or
- the numbers of mine workers that could reasonably be expected to be in an area at any time divided by the nominal capacity rating (in persons) of the ERSs.

Where any person is required to travel or work more than 750 m from an ERS, a special permit which details some other arrangement is required, eg a longer duration self-contained self-rescuer.

Other requirements for locating the ERS are given in Appendix A.

For practical reasons it was decided to standardise on a single 'size' of relocatable ERS. Based on considerations of the maximum container size that can fit in the mine shaft cage (if there is no surface ramp access), and the maximum number of persons likely to be working within 750 m of ERS sites, this was determined to be eight persons. Therefore each relocatable ERS needed to be able to keep eight persons safe for eight hours. Where more than eight persons could reasonably be working at any time, an additional ERS is required.

CHOICE OF BREATHABLE AIR DELIVERY SYSTEMS

There is a variety of options available for supplying persons with breathable air for eight hours. However, the provision of compressed breathing air from cylinders using individual face masks or from cachéd self-contained self-rescuers was *not* chosen for the following reasons:

- 'therapy' masks are unsuitable for refuge; proper breathable air delivery masks are required;
- if more than eight persons came to a relocatable ERS, there would be insufficient masks or cachéd SCSRs. If 'spare' masks or SCSRs are put in each ERS, then this negates the concept of a nominal capacity;
- the logistics, practicality, cost and maintenance checks required to store the large number of masks/SCSRs which would be needed for the fixed ERSs (cribrooms);
- the distress caused to mine workers when required to sit for many hours with a face mask/SCSR on;
- the problems of positive pressure (supply) masks: if one of these is turned on with no one wearing it, the supply of air to the remaining masks will be rapidly expended;
- the problems of negative pressure (demand) masks with sealing around facial hair;
- mask/SCSRs assume the refuge station has become or could become contaminated with fumes (ie is not gas tight). To be consistent, this means goggles must also be worn;
- masks/SCSRs make it difficult or impossible to drink water, an essential requirement for long, healthy entrapment in summer;
- masks/SCSRs make it difficult or impossible to communicate with other workers; and
- masks/SCSRs make any first aid treatment of injured workers difficult, and make administering expired air resuscitation impossible if a worker were to collapse.

These factors reduced the number of breathable air delivery systems to:

- compressed mine air,
- compressed bottled medical air (with no masks),
- oxygen supply and carbon dioxide scrubbing devices, and
- use of 'dead air' space, ie relying on the initial uncontaminated atmosphere within the refuge station itself.

---

1. Principal Consultant, Mine Ventilation Australia, 12 Flinders Parade, Sandgate Qld 4017.

2. Senior Lecturer in Physiology, School of Public Health, Curtin University, Perth.

† This distance was reduced to a maximum of 375 m for workers who are not wearing SCSRs (Five minutes travel @ 4.5 kph walking speed).

‡ There are Australian standards for breathable air systems [AS1715 and AS1716] but these do not really address the needs of a refuge station.

The problem of keeping toxic fumes out of the ERSs means the ideal system puts the ERS under positive pressure (ideally 200 to 300 Pa) with respect to the external environment. This is true because mine workers will not all arrive at once, which means any door must be opened and closed several times, each time potentially resulting in some contamination of the inside air if not under positive pressure, and some doors are unlikely to be absolutely gas-tight even when closed§. New designs must be tested with a tracer gas technique such as SF_6 to check for gas-tightness and contamination potential.

All breathable air systems must be able to be started and stopped from inside the ERS, must be reliable, and in the case of the relocatable ERSs, mechanically robust and easily connected to services to assist in the relocation process.

BREATHABLE AIR

Normal dry air, at standard temperature and pressure (STP of 101.325 kPa and 0°C), consists of 20.95 per cent oxygen, 78.08 per cent nitrogen, 0.0314 per cent carbon dioxide, 0.93 per cent argon and trace amounts of 14 other gases. It may be noted that these are expressed by *volume*; the proportions are different if expressed by *mass*.

For humans, there are two principal metabolic fuels. Glycogen (carbohydrate) is the primary fuel used by muscle as workload increases. It has an RQ (respiratory quotient) of 1.0. RQ is the steady state ratio of the volume of carbon dioxide produced to the volume of oxygen consumed. Fatty acids, the other metabolic fuel, are used more at rest and have an RQ of 0.7. The average RQ that results from constant low levels of activity, as expected in entrapped conditions, is about 0.80. This RQ can then be used to then calculate the amount of carbon dioxide produced as oxygen is consumed. The metabolism of one litre of oxygen produces 20 kJ of metabolic heat.

At complete rest and in a non-stressed state, a 70 kg person will breath in air at a rate of about 7.5 litres per minute and expire air at 17 per cent oxygen and 3.2 per cent carbon dioxide. This results in a 'resting' oxygen uptake of 0.3 litres of oxygen per minute and a resting carbon dioxide discharge of 0.24 litres per minute. However, the rate of breathing is primarily triggered by the carbon dioxide content of inspired air with higher carbon dioxide levels triggering faster respiration rates❖. Moreover, it does not take a significant increase in activity levels, or body weight, to make a substantial increase in metabolic rates and thus oxygen consumption and carbon dioxide production. Venter *et al* (1998a) found an average oxygen consumption for 12 entrapped individuals of 0.44 litres per minute, at STP, over 24 hours (including sleeping). A figure of 0.5 litres per minute over a non-sleeping entrapment period of 12 hours is a prudent, conservative design value. This corresponds to a metabolic rate of about 160 W or 80 W/m² for a typical miner with a body skin area of about 2 m², which is equivalent to a breathing rate of about 12.5 litres per minute of fresh air.

§ Note however, that in tests conducted by Venter, in which the door was opened for five seconds each of 12 times, minimal contamination of the refuge station occurred. Venter found that sealing of the refuge station when the door was *closed* was much more significant that the small ingress of contaminants when the door was briefly opened (Venter, pers comm). Kielblock *et al* (1998) simulated an ERS door being opened 30 times for five seconds per time (simulating 30 people entering a (larger) ERS at various times) and found that the ingress of contaminants during door-opening was negligible compared to the contamination by leakage over the subsequent hours. This assumes the ERS has not been contaminated with products of combustion (POCs) before the occupants arrive.

❖ Care should be taken with all these numbers as they are only true at standard pressure. For mines which are well above or below sea level, or where temperatures will be above 0°C (which is usually the case), these numbers will change significantly and specialist advice must be sought.

Carbon dioxide

Carbon dioxide is twenty times more soluble in blood than is oxygen (McPherson, 1993). As the carbon dioxide content of the inspired air rises, the breathing rate becomes faster. Normal air is 0.03 per cent carbon dioxide or 300 ppm. The TLV-TWA (time-weighted threshold limit value) for carbon dioxide is 5000 ppm (0.5 per cent)⌘, headache and an increased rate of breathing occur at 10 000 ppm, the TLV-STEL (short-term exposure limit) is 30 000 ppm (resulting in a doubling of normal breathing rate), panting and intoxication occur above 50 000 ppm with unconsciousness occurring at about 100 000 ppm.

These figures apply where the oxygen content of the air is *normal*. Note that the *maximum* carbon dioxide content in self-contained self-rescuer operation, under the European Standard EN401-1993 (Chemical Oxygen Escape Apparatus), is limited to a maximum of three per cent or 30 000 ppm (and to an average of 1.5 per cent).

Oxygen

Perhaps surprisingly, a declining oxygen content triggers only a minor increase in breathing rate, this being governed by the carbon dioxide content of inspired air as discussed above.

The normal lower working limit for oxygen is 19 per cent. At 18 per cent there is a slight increase in breathing effort. At 16 per cent, a flame lamp will go out, but this still continues to trigger only a slight increase in heart and breathing rates. At 14 per cent, emotional upset, impaired judgement and faulty co-ordination occur. At 12 per cent, cardiac damage can occur along with vomiting. At ten per cent, a person would lapse into unconsciousness and death (Hartman *et al*, 1997).

Again, these figures apply where the carbon dioxide content of the air is *normal*. Note that the *minimum* oxygen content in self-contained self-rescuer operation, under the European standard EN401, is limited to 21 per cent with an excursion to 17 per cent for up to two minutes at the start of SCSR operation. The minimum oxygen content under the *Guidelines for Safe Mining* (Anon, 1996) is 17 per cent whilst the minimum allowed under Worksafe Australia Standard is 18 per cent (Anon, 1990).

Oxygen and carbon dioxide limits

There are no known hard and fast rules for establishing *simultaneous* limits to low oxygen and high carbon dioxide concentrations for emergency situations (Schroder, 1989). However, based on EN401 guidelines for self-rescuers, the analysis given above, and the fact that the combined physiological cost to the body of simultaneous low oxygen and high carbon dioxide levels will be greater than that if only one or the other were to occur, suitable 'emergency' working limits for the design of ERSs would be:

- for 'open' systems such as compressed air: 19 per cent oxygen and 0.5 per cent (5000 ppm) carbon dioxide; and
- for 'closed' systems, 18 per cent oxygen and 1.25 per cent (12 500 ppm) carbon dioxide, which is also in accordance with other guidelines (Anon, undated).

It can be shown that for a person breathing at a rate of 12.5 litres per minute within a 'dead air' space of one cubic metre, an oxygen level of 18 per cent will be reached at 58 minutes, whereas carbon dioxide levels will reach the TLV of 0.5 per cent at only 12 minutes, and the 'upper' working limit of 1.25 per cent at 30 minutes. *This indicates that the air supply to an ERS is governed by the rate of build-up of carbon dioxide, and not the drop in oxygen.* It is clear that the old adage to 'crack the air line until you can hear the airflow' is unlikely to be a satisfactory arrangement when using compressed air in an emergency refuge station. This has been confirmed in 24 hour tests done by Venter

⌘ Which is also the limit prescribed by Worksafe Australia, except for 'coal mines' where the limit somewhat curiously is 12 500 ppm.

(1998a), which showed unsustainable carbon dioxide build-up where the adage of 'cracking open the compressed air line' was followed.

Furthermore, in these same tests Venter observed that participants noticed and commented when carbon dioxide levels reached one per cent, whereas there was barely any comment when oxygen levels had fallen by as much as six per cent in the same tests.

High oxygen limits

Some of the chemical devices for providing oxygen result in very high levels of oxygen in the chamber. Those that rely on oxygen being released from compressed oxygen bottles can obviously be regulated. However, those that rely on the decomposition of sodium chlorate (ie oxygen candles) typically release the entire volume of the decomposition (about 2800 litres) in 90 minutes or so. This can result in oxygen levels of over 50 per cent in the enclosure (this is not an explosive atmosphere, but will make any naked light burn more intensely than normal). Oxygen levels of 100 per cent can be tolerated by healthy persons, without adverse effects, for at least 12 hours. Oxygen levels of 50 per cent are acceptable indefinitely. In fact, the standard treatment for carbon monoxide poisoning involves oxygen therapy. Therefore, high oxygen levels in the chamber when miners arrive is probably a useful benefit, given the possibility of miners having had to travel through products of combustion en route.

BREATHABLE AIR SYSTEMS

Compressed air

It has been previously shown that an oxygen uptake of 0.5 litres/minute is a good design figure for entrapment. To ensure the carbon dioxide content levels out below the TLV-TWA of 0.5 per cent, a fresh air supply of 85 litres per minute per person is required. This flowrate will result in a 'steady state' oxygen content of about 20.3 per cent. Lower supplies of fresh air are sometimes quoted (eg 2.5 cfm per person which is about 70 litres/minute); however, these are based on unstressed, resting breathing rates (7.5 litres/minute) with an equivalent oxygen uptake (0.3 litres/minute) and do not allow for any additional persons (above the design figure) inside the ERS.

For eight persons over eight hours, this standard of 0.5 litres/minute requires delivery of 1.9 m^3 of oxygen and scrubbing of 1.54 m^3 of carbon dioxide, or alternately, delivery of 326 m^3 of breathable air.

Unless there is a dedicated compressed air line to surface via a borehole[✗] or other route where there is no significant risk to the pipeline, compressed air cannot be considered to be a fail-safe supply of breathable air. However, security can be enhanced by constructing high-risk sections of the line using screwed pipe. Furthermore, if the assumption is made that most persons will be at safety within five minutes, and all persons will be at safety within 18 to 30 minutes[ø] of notification of the fire, then it is less likely that the compressed air system will be compromised in this space of time. For fixed ERSs, activating the compressed air supply as soon as the fire alarm is raised reduces the need to ensure that cribroom doors are always closed (not practical), that they always have a perfect seal to prevent ingress of fumes (not practical), that they have working air locks (not practical) and that these air locks are actually used properly in a panic situation when a miner enters from smoke (unlikely).

Therefore, compressed air is supplied to the fixed ERSs as the primary breathable air supply, and is automatically activated when the fire alarm is raised. Security of the airline is high (refer Appendix C). This ensures these lunch rooms are under positive pressure while all of the workers are getting to the refuge stations.

Maintaining positive pressure in an ERS which does *not* use compressed air is more problematic. However, oxygen generating systems [whether medical-grade air, sodium chlorate ($NaClO_3$) or potassium superoxide (KO_2)] all produce some positive pressure. Furthermore metabolic energy also produces some positive pressure by the conversion of food, water and oxygen into carbon dioxide and water vapour. For further details, refer to Anon (1997) 'Respiratory Losses' and the metabolism example above. If the air inside the ERS heats up significantly, then this will also produce a positive pressure, according to Boyle's law. Conversely, if the ERS has a refrigeration system which starts up after occupation begins, then the ERS may end up under negative pressure, in which case the integrity of the sealing systems is crucial.

Therefore, mine compressed air is a suitable primary means of providing breathable air for ERSs where the airline is relatively secure. However, mine air, even if generated on the surface where the compressors cannot be contaminated by the fire, is not a 100 per cent reliable system. Even steel pipe, or the joiners between sections of pipe, can be burned out in a major fire or broken by a rock fall triggered by a major fire. This can result in loss of compressed air pressure[ж], or contamination of the compressed air by the fire (ie as the fire burns the rubber couplings out, the venturi effect from the compressed air flowing in the pipe can suck in contaminating fumes, which was exactly the case in a major fire at the Ruttan Mine in Ontario on 6 October 1990). Therefore a back-up system is required. By deduction, this back-up system needs to be either bottled air, or a scrubbing device or the dead air itself.

Any mine compressed air system must include suitable and properly designed filtration and noise suppression, must also allow for manual open and closing, and must provide a manual 'purge' to allow the routine bleeding of water from the line and bleeding of stench gas from the line in certain circumstances. Noise levels in excess of 110 dBA have been recorded with unattenuated compressed air systems inside refuge chambers (Kielblock *et al*, 1998). Not only is this injurious to hearing, but it will make essential person-to-person and telephonic communication virtually impossible.

Dead air space

Dead air space can be used as either the primary or back-up air supply, depending on the circumstances.

Calculation of the drop in oxygen content and of the increase in carbon content over time depends on the initial volume of the ERS, the number of persons inside and their metabolic rate. Charts such as those developed by US National Aeronautics and Space Administration (NASA) can be used for these calculations, but because of the high stress levels during emergency entrapment, a better approach is to use equations developed from first principles. These use the starting volumes of oxygen and carbon dioxide in normal air and the rates of consumption and production of these gases given off at various metabolic rates.

In many mines, calculations will show that dead air space is a viable supply of breathable air for the cribroom-sized, fixed ERSs, but is not a viable supply of breathable air for the relocatable ERSs.

✗ Boreholes are popular with some coal mines; however, this is a function of the two-dimensional nature of coal mines and their normally relatively shallow depths of operation.

ø 30 minutes being the rated, nominal capacity of the SCSRs in use at many underground mines, and 18 minutes being an accepted design (de-rated to 60 per cent) capacity. Longer-duration SCSRs will require recalculation of travel times and distances. With a 750 m maximum travel distance, an 'average' travel distance of 375 m would take five minutes at 4.5 kph.

ж Calculations based on the assumption that the compressed air line was broken at any one of a number of locations are needed to establish if pressure and volume at the main ERSs will remain acceptable. However, an ERS fed by the broken line would obviously be affected.

Chemical oxygen supply and carbon dioxide scrubbing

There are only two options remaining for supply of breathable air for ERSs. This is compressed medical air (or medical-grade oxygen in cylinders) or technology which produces oxygen by the decomposition of a chemical substance and absorbs carbon dioxide using another substance. Commercial devices such as the oxygen candle technology in the Rescueair-E™ ☙ or compressed oxygen technology such as Refuge One™ ● are available. Both devices rely on scrubbing of carbon dioxide using soda lime✦. Each technology produces different levels of heat, and also different positive pressures within the ERS. Detailed studies are required to identify the best option for the circumstance.

Medical air cylinders

A typical arrangement such as a 'J pack' consists of 15 off G size cylinders, in total containing a nominal 175 m^3 of medical air at standard temperature and pressure, pressurised to 25.3 Mpa. The plan area size of the J pack is 1.5 × 0.9 m. Total weight of the pack is 1.6 tonnes. Two J packs would be required for eight persons for eight hours.

As discussed previously, it is usually unsatisfactory to use oxygen masks with bottled air and the air must be discharged directly to the atmosphere within the ERS.

SPECIFICATION OF ERSs

The standard specification for an ERS is given in Appendix C. It is important to recognise that all ERSs need to be regularly inspected to ensure they remain fully operational.

TEMPERATURES IN EMERGENCY REFUGE STATIONS

It is very common to misjudge the heat build-up when a number of 'resting' persons are placed inside a restricted space. In the infamous 'Black Hole of Calcutta' incident, 123 of the 186 British soldiers died when imprisoned for only one night. Likewise, in the Kosti disaster in the Sudan, of 281 civilians imprisoned in one room for one night, 194 died (Leithead and Lind, 1964). The often-used shipping-type container or 'steel box' placed underground will simply become a coffin, and not a refuge bay, for miners trapped for any significant length of time in many mines in Australia.

A person consuming 0.5 litres of oxygen per minute generates about 160 watts of heat. Therefore eight persons in an ERS could generate the same heat as a 1.3 kW bar heater.

Moreover, there are other sources of heat inside an ERS, which include:

- electrical equipment, including fans for scrubbers and DC power supplies or AC inverters,
- emergency lighting and caplamp lighting (small quantums),
- any heat of oxidation from carbon dioxide scrubbing, or decomposition from oxygen reactions,
- any heat gains or losses from compressed air, or water flowing into/out of the ERS, and
- radiative or convective heat gains/losses from the ERS to the surrounding air.

Over time, the temperature inside an ERS will increase. Venter *et al* (1998a) found that even with relatively low starting temperatures of around 25 degrees, a small 'shipping container' with eight persons in it will develop very stressful temperatures (29 wet bulb (WB), 29 dry bulb (DB), ie fully saturated) within about 60 minutes. Kielblock *et al* (1988) likewise found that the temperature in an ERS climbed from 20.9 WB to 35 WB in 90 minutes after the compressed air failed. Excessive heat stress and the development of heat illness for those trapped inside is likely, even if the toxic gas concentration is satisfactory.

Note that autocompression alone (before any other heat sources such as strata heat or diesel equipment) means that average wet bulb temperatures in a 1000 m deep mine are about 4° above surface wet bulb temperatures and average dry bulb temperatures can be up to 10° above surface dry bulb temperatures (depending on moisture pick-up). The distribution of underground wet bulb temperatures in a mine with well maintained ventilation has a standard deviation of about 2°. Thus, knowing the maximum surface design, a *rough* indication of the *minimum* expected wet and dry bulb underground temperatures surrounding an ERS can be calculated for a mine at feasibility study stage. However, a proper underground environment simulation study should be used prior to finalising any design.

Underground starting temperatures inside relocatable ERSs will typically be the ambient underground temperatures, which on a hot summer's day in many mines in Australia is about 28° wet bulb and 34° dry bulb. Starting temperatures inside fixed ERSs which have continuous refrigerated airconditioning, will be about 16° to 18° wet bulb and 24° dry bulb.

Humidity inside an ERS will increase with time, because:

- expired air (ie expired breath) is always saturated with respect to moisture vapour. With typical expired air temperatures of 35°, moisture content will be 34 g water per cubic meter of expired 'dry' air. Each miner will therefore expire about 30 mL/hr of moisture vapour, and
- sweat rates between 0.5 and 2.0 litres per hour per miner are credible for unrefrigerated ERSs. However, as the human gastric emptying rate and gut absorption rate is limited to about 1.4 L/hr, progressive dehydration will occur at high sweat rates, even with unlimited access to water.

Contrary to popular belief, 'compressed air' coming out of a pipe, if it does no useful work, is at the same temperature as the pipe itself, ie ambient conditions. Any cooling effect from compressed air is due to the high velocities at the discharge, and the low humidity levels in the compressed air, both of which assist in evaporation of sweat from the body* and in the reduction of the wet bulb temperature. However the compressed air will only assist in cooling to the extent that it reduces the average humidity levels in the chamber (and hence the wet bulb temperature), unless temperatures inside the chamber become greater than those outside, in which case some sensible heat transfer will also occur.

Separate calculations of dry and wet bulb temperature increases inside the ERSs need to be made, both for the primary and back-up sources of breathable air. A computer program was written to simulate the environmental and physiological state of persons inside an ERS. The cut-off point for survival times in the ERS was governed by:

- deep body core temperatures, which were restricted to a maximum of 39°; and
- wet bulb temperatures inside the ERS, which were limited to 35° WB, based on war-time and other experiments and summarised by Leithead and Lind (1964).

It should be noted that these are very stressful limits.

☙ This is an oxygen generating (sodium chlorate) and carbon dioxide scrubbing device using technology similar to that used on many submarines. It decomposes exothermically to oxygen and common salt according to the reaction: $2NaClO_3 \rightarrow 3O_2 + 2NaCl$.

● This is a bottled oxygen and carbon dioxide scrubbing device using similar principles to most mine rescue breathing apparatus, except on a larger scale.

✦ Soda lime consists of 80 per cent calcium hydroxide, three per cent sodium hydroxide and 17 per cent water. The exothermic reaction is as follows: $CO_2 + H_2O \rightarrow H_2CO_3$; $H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$; $Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH$ + heat.
116 gram of soda lime can adsorb one mol (22.4 litres @ STP) of carbon dioxide.

* For example, assuming compressed air is coming from a pipe at 35°C (ambient conditions around the pipe) and at 500 kPa and was originally saturated at its initial pressure of 700 kPa, each five litre/sec of compressed air generates 1.1 kilowatts of refrigeration (kWr).

It is also critical to realise that the 'starting' core temperature for most workers who have been engaged in physical work under thermal stress could already be up to one degree above 'normal' (ie up to 38° C), and persons could also start out at up to two per cent dehydrated (the onset of the 'thirst' response). These are therefore sensible starting conditions to assume for ERS calculations.

Under a 'no airflow' scenario, core temperatures increase rapidly, which indicates the human thermoregulatory system is under great strain. In these conditions, a limit of 39° for core temperature is not realistic as it assumes that when this 'cut-off' point is reached, persons are withdrawn to a cool environment (ie no 'overshooting' occurs). In a rescue situation, even after a mine rescue team arrives, it could be a considerable time before trapped persons are in cool conditions. Therefore, the limit of 35° WB inside the ERS is the more appropriate limit. This limit is also reached much earlier than the 39° core temperature limit and in this sense is 'conservative'.

Therefore, to maintain steady state temperatures inside an ERS, a cooling system that can remove at least 8×160 W (=1.4 KWr) plus heat from other internal and external sources needs to be established.

Studies of various simulations led to the following conclusions:

- high rates of compressed air flow would be needed to keep the ERSs within acceptable cooling limits in mid-summer at their design capacity of eight persons;
- good airflow over the skin would be required;
- miners would need to strip down to minimal clothing;
- if the compressed air system was to fail and other means of cooling are not available, survival times would be limited to an unacceptably short duration; and
- if the primary ventilation system was to fail, resulting in increasing ambient air temperatures outside the ERS and increasing temperatures of the compressed air, survival times would again be limited to a short duration.

OPTIONS FOR COOLING

There are several options for cooling an ERS:

- Split refrigerative air-conditioning systems. 'Off the shelf' mains-powdered units, which are designed for installation in fixed surface buildings, will not be robust enough for relocatable, skid-mounted underground refuge stations. Moreover, being mains powered, they will cease operation if the power supply fails. A back-up power supply (diesel generator) would further complicate the arrangements and would breach the key guidelines of the egress strategy being simple and robust. However, purpose-built refrigerative air-conditioners are now available that run from an AC inverter fed from lead-acid batteries, which are themselves constantly 'trickle charged', ie a system much like an uninterruptible power supply. This is a practical option for relocatable ERSs in ambient conditions up to 40 degrees. Insulation on the ERS is required, in which case a small eight-man ERS can maintain satisfactory temperatures with a 3 kWr refrigeration unit.
- 'Cold guns' of the vortex tube type, which can provide refrigeration capacity of up to 1.5 kWr per unit. These are compressed air devices with no moving parts, are relatively inexpensive and require little maintenance. However, if the compressed air has not failed, refrigeration is not required, and if the compressed air fails, then the vortex tubes will not work; moreover, it would be very difficult to ensure these devices do not allow noxious gases into the ERS after the compressed air fails. These devices are also very noisy, and installation of a muffler will increase the back-pressure on the device and seriously affect its performance.
- Alternately, vortex tubes could be operated off medical air cylinders. As the vortex tubes sacrifice about one-third of the air to reject the heat, this would reduce the duration of the cylinders. Again, however, the difficulty of ensuring noxious gases do not enter the ERS using the vortex tube discharge port ruled this option out. Therefore vortex tubes are not suitable as a solution.
- Use of chilled or unchilled service water. The service water would need to be hosed over the body. Whilst there are some scenarios in which this is theoretically possible, in most mines it will not be practical. It would require water-proofing of electrical equipment and one-way (no gas return) drain holes and would be exceedingly uncomfortable. Except in site-specific circumstances, this is unlikely to be a unsatisfactory long-term, robust solution.
- Cold vests (such as those used by fire fighters). These can provide up to 1600 kJ (about two hours per jacket for a person with a metabolic heat load of 160 watts) of cooling. A refrigerator would need to be provided in each ERS with its condenser outside the ERS. If and when the compressed air or power were to fail, the cold vests would provide the necessary cooling. Preliminary indications are that two cold vests per person could provide comfortable conditions for four hours. However, for practical reasons and because of the time limitations, this option is also unsatisfactory.
- Stored ice. This option requires a large block of ice to be frozen inside an ERS in a freezer. In the event of a power failure, the block slowly melts soaking up external heat according to the sensible and latent heat of melting. The practical difficulties in doing this would need to be resolved prior to introduction; however, it remains a possible low-cost option.

It is critical to recognise that most underground mines in Australia which rely on 'shipping container' type designs for ERSs will be unable to keep occupants alive for eight hours during summer conditions unless some form of cooling is provided. The need for a cooling strategy does not just apply for deep mines in the northern part of the continent.

THE PSYCHOLOGY OF ENTRAPMENT

Any real emergency which results in 'entrapment' of underground workers will create panic and high levels of anxiety. For a trapped underground worker, especially if alone, there may be little difference between 'entrapment' and 'entombment'. Venter (pers comm), after conducting 24 hour entrapment *exercises* (ie low stress compared to a 'real' entrapment), report the following:

- Heart rates and oxygen consumption initially increased (due to an increase in anxiety) when the lighting was unexpectedly turned off inside an ERS .
- Any concerns expressed by the leader about the effectiveness of the oxygen or carbon dioxide systems resulted in increased heart rates and oxygen consumption.
- Trapped workers' heart rates and oxygen consumption decreased markedly when they commenced playing cards or other such activities.

It is crucial, if at all possible, to keep trapped persons informed about the progress of the rescue activities. 'No news is good news' does *not* apply for anxious trapped workers, who will inevitably fear that rescuers may not reach them in time, etc.

Hence reliable communication (at least one way) between the rescue command centre is very highly desirable, as is a 'fail safe' environmental system and the provision of such simple relaxation activities as a few packs of playing cards.

CONCLUSIONS

A comprehensive emergency egress plan is required for all underground mines which will result in acceptably low levels of residual risk for the workforce, even in the event of a remote probability catastrophe such as a major fire underground. A key component of this strategy is the siting and specification of suitable Emergency Refuge Stations to contain all persons underground at the time of the incident starting, until they can be rescued.

For most mines in summer, maintaining safe temperatures within an Emergency Refuge Station is the most difficult criterion to meet, in terms of an eight hour minimum entrapment. The second most difficult criterion to meet is maintaining carbon dioxide levels. Maintaining sufficient oxygen is the easiest criterion to meet.

Whilst the guidelines identified in this paper are not cheap to implement, it should be recognised that the fire protection and fire escape systems in a large surface building cost between two and five per cent of the total cost of the building. An underground mine is, if anything, more hazardous; is it not reasonable to expect that underground workers should have a similar chance for safe escape from a fire as surface or office workers?

It is important to recognise that the specifications adopted are dependent on the hazards at the *individual* mine and the resulting total and residual risk profile. This must include site specific factors such as summer temperatures, underground heat loads and the depth of mining. The conclusions in this paper should not be copied into other operations without a full risk assessment being carried out to identify and assess these site specific issues.

APPENDIX A
LOCATION OF EMERGENCY REFUGE STATIONS

- On main or normal routes of travel where they achieve high visibility and high workforce recognition, wherever practical.
- Where more than one ERS is required on a level, they should be located so as to maximise the options workers have to access the ERSs from different directions/routes.
- At least 60 m from an explosives magazine.
- At least 15 m from a transformer greater in size than 5 kVA.
- So that a fire in a parking area or refuelling bay will have minimal effect on the ERS.
- Sufficiently distant from any combustible material so that the ERS cannot catch on fire and so that direct access from the thoroughfare to the ERS cannot be blocked off by fire.
- Away from any place where they will be damaged by concussion in stope blasts.
- To have a 'stop log' or very strong barricade to ensure vehicles cannot park in front of them or back into them.
- Where practical, to be located where there is a second egress and/or access for mine rescue teams. A self-contained ERS can also be effective in acting as a 'staging post' for a mine rescue team. A back-up rescue crew, or back-up equipment could be positioned at the nearest ERS upwind of a fire. Alternately, first aid to injured persons could be administered in the ERS. Because even a small ERS should be able to operate without initiating the oxygen-generating or carbon dioxide scrubbing systems for up to one hour after occupation using its 'dead air' space, use of an ERS in this role (with air-conditioning) has no significant costs attached.
- Where they can be towed or carried into position with no damage to the ERS or the towing machine or forklift.
- So they have ready access to utilities (telephone, power, etc).
- Where they cannot be flooded.
- Where the ground is sound and good roof support is in place.
- To be located after consultation with the relevant mine rescue leaders, who may want to examine alternative routes for retrieval/rescue of personnel if the main access to the ERS is blocked.
- Even though the 'design capacity rating' of a ERS should not be placed on the ERS (this could imply that once this number is reached, people are then to be turned away!), it is important to recognise a 'rating' for the purposes of deciding if and where more ERSs are required because of the numbers of people working in a high-activity area.

APPENDIX B
SPECIFICATION OF MINE COMPRESSED AIR SUPPLY TO EMERGENCY REFUGE STATION

- Provision of a properly sized, secure (good hangers/ties) preferably-screwed compressed air line, preferably painted or signed so it is not interfered with.
- The airline should discharge to the back of the ERS, at the opposite end to the entrance door.
- The airline needs a filter, regulator and a silencer. The regulator should be pre-set to the airflow required for the number of people in the room; however, the filter, regulator and silencer must be designed to operate under both normal mine air pressures and *below normal pressures* in the event of the air line being damaged.
- Manual override is required for the regulator in the event of low compressed air pressure (eg the line has been damaged or contamination of the compressed air has occurred).
- The regulator should be designed so that it will not freeze up under the range of conditions that could be encountered during emergency egress.
- Airline discharge is activated on confirmation of *any sized fire or smoke detected or suspected*. This must be able to be done remotely be a responsible person (eg the person who gives the mine evacuation command), locally from within the ERS, and also, in the case of fixed ERSs which usually have a fan and vent duct feeding fresh air into the cribroom, operated by a smoke detector which also closes the fan feeding the cribroom, which in turn operates a self-closing damper on the duct inlet to the cribroom.
- A purge line *outside* the cribroom, which can be opened and closed from a simple mechanical valve *inside* the cribroom, would allow someone in the cribroom to purge the first few minutes of air from the line for maintenance or other reasons.
- A pressure relief valve at the opposite end to the airline discharge to ensure pressures do not become excessive within the ERS.

APPENDIX C
GENERAL SPECIFICATION OF EMERGENCY REFUGE STATION

- Fail-safe breathable air supply, or primary supply with .back-up.
- Brick walls used in the external construction of the ERS to be painted to avoid gas leakage. Two coats of oil-based paint are required.
- For the fixed ERSs, a dedicated screwed water line, clearly marked, which is also used for day-to-day water supply to the cribroom to avoid problems with bacterial growth in the water.
- For the relocatable ERSs, a store of cachéd water, replaced at appropriate intervals, along with drinking cups.
- Telephone and AutoPED[≈]. Essential telephone numbers must be on a sign near the telephone.
- A sign with the unique name of the ERS must be inside the ERS to ensure that all persons, even those unfamiliar with their location, can identify exactly where they are.
- No smoking signs outside and inside the ERS.
- Provision of a very basic emergency toilet, toilet paper, note books and pens (for taking names of persons, instructions, measurements, etc), stretcher(s) [site specific] and trauma kit, playing cards (one pack per four persons) and masking tape

≈ AutoPED is a reliable one-way communication device, based on similar technology to that used to contact deeply submersed nuclear submarines, installed as a fixed installation.

(for emergency sealing of cracks) all housed in a locked wooden cabinet, with 'in case of emergency, break glass'.

- Note that a 3 mm crack around a door leaks five litres/s of air per metre of crack when under 120 pascals. Therefore sealing is important to avoid possible contamination of the station, even when under positive pressure from the compressed air.
- The door to the ERS should be single, steel clad and should be outward opening with a good seal.
- The ERS should be clearly marked as 'Emergency Refuge Station' and optionally painted in the Australian standard green and white for emergency facilities.
- The turn-off from the main thoroughfare to the ERB should be whitewashed to ensure prominence and high recognition for the ERB.
- Siren and flashing light outside the ERS (visible and audible indicators) activated automatically on issue of the mine evacuation order with manual override (so they can be turned off after a suitable time) and battery (UPS) back-up. Orange lights have been shown in South African studies to be the most visible colour in smoke.
- Optionally, an ERS which is less accessible or visible from the main thoroughfare should have guide cones installed from the main thoroughfare to the ERS.
- ERS external walls should have one hour fire rating.
- Internal emergency lighting much the same as in a surface building. In the fixed ERSs, this also helps people find caplamps, etc if there is a power failure during other circumstances.
- If temperatures in the ERS could reach levels that result in serious health problems, a method of cooling the occupants.

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DOCUMENT 8

Design and Installation of Refuge Chambers

JW Oberholzer
Simtars

Some examples

- Courriers mine in 1906 coal dust explosion -

20 days after the explosion 13 survivors found their way out of the mine and another man 5 days later.

South Africa

- Hlobane, 1983: 68 dead - Self-rescuers coalmines.
- Kinross,1987 : 177 dead - Self-rescuers goldmines.
- Middelbult, 1993: 53 dead - Leon commission.

Australia

- Moura No. 4, 1986: 12 dead - Filter self rescuers, Flame proof lamps.
- Moura No. 2, 1994: 11 dead - Filter self rescuers. Warden's Inquiry led to the development of new safety standards.

Points to discuss

- How did matters occur in South Africa.
- Why refuge bays in SA.
- What were expected from them.
- The progress in Queensland.
- Some experiences.
- Present feelings.

The SA Coal mining environment

- Long distances to sections(3-4 kms)
- Sections over a km in length
- Mostly bord an pillar mining
- Up to six sections per shaft
- Up to thirty people per section

Workers would be in large numbers and geographically expanded

Decision to install refuge bays

- Scenario development and planning.
- No alternative solutions to identified problems.
- Best horse for the course.
- Drew up general specifications.
- Mines to develop details.

Design issues -SA

- To withstand an overpressure event of 20psi.
- First one needs to be within 600 meters from where workers work.
- Needs positive pressure inside bay – air supply.
- Doors to create seal.
- Well signed or identified.
- Communications to surface.
- Provision of food, water and sanitation facilities.

Air supply

Reason

- Supply of breathing air.
- Creation of positive pressure.
- Cooling of environment.

Method

- Compressed air - where it is available.
- Surface borehole with fan.
- Oxygen generators or bottles. (no pressure)

Communication issues

- Need for leadership.
- Cannot communicate with SCSRs and only limited when using CABAs.
- Problems with one-way communications.
- Need for consolidation of actions.

Historic proof

- Refuge bays have worked in South Africa and have saved lives. (elsewhere as well)

- Gloria - even after four days.
- Emaswati- colliery.
- Canada and Tasmania

- People have also died in mines with refuge bays.

The QLD mining environment

- Low numbers of workers.
- Concentrated mining. (high seams, LWs)
- High air speeds- quick pollution.
- Less prescriptive regulation.
- High emphasis on management of risks and use of safety management plans.

Changeover and communication stations

Task group 4 Recommendations

- Intervals based on person travelling on foot.
- Readily locatable and accessible.
- To resist low intensity explosions.
- Provided with respirable air.
- Provided with robust communications.
- Method to determine toxicity and oxygen content of air.
- Sized to cater for demand.

Emergency exercise experience.

- Communications a problem.
  SCSRs and CABAs
- Changeover to EBAs a problem.
- Social environment could cause problems.
- Decision making in aftermath –time problem.
- Travelling and escape routes can be beyond the capabilities of rescue crews. (2 mile long walls)
- Not all men are equal.
- Even in the simulated exercises, things are not that easy.

Historic reality- QLD

- Have held exercises every year.
- Have identified issues and made alterations.
- Industry is highly committed.
- Have had successes and failures.
- No real emergencies have occurred to test the present systems.

Some concluding thoughts

- Refuge bays, emergency shelters , safe havens , changeover stations – same concept.
- Not easy to install and maintain.
- Quite a few alternatives.
- Not the only solution, just part of a system.
- Must suit, and fit in with system at the mine.
- Costs money, effort and other resources.
- The alternative??

DOCUMENT 9

Emerging Technologies: Aiding Responders in Mine Emergencies and During the Escape from Smoke-Filled Passageways

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ABSTRACT

Historically, underground mine rescue teams have received training only in the course of actual emergencies, or in simulated mine environments, usually on the surface, with placards to identify objects and hazards. Also, while U.S. Federal Regulations require all underground miners to walk escapeways and conduct fire drills every 90 days, this does not fully prepare them for the conditions that may be encountered in real escape situations, such as smoke filled entries. This paper describes technology and realistic training simulations that have been identified for the general workforce and mine emergency responders. Of all the technology evaluated by underground personnel, laser lights and lifelines were most beneficial in leading personnel to safety and out of the mine in smoke-filled passageways. These technological advancements can improve the state of readiness for rescue personnel and increase the chances of survival for personnel escaping from underground emergencies.

INTRODUCTION

Mine rescue teams are often called upon to save lives during an underground emergency such as a fire, explosion, roof fall, or water inundation. It is extremely important that team members are provided with adequate exploration and recovery equipment and be properly trained in the use of that equipment. Over the past several years, the National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Research Laboratory (PRL), in collaboration with state agencies and several mining companies, has developed, conducted and evaluated mine rescue training simulations, in-mine smoke training exercises, and mine emergency response drills (MERD) at its Lake Lynn Laboratory (LLL) near Fairchance, PA and operating mines. These training simulations allowed rescue personnel to train under realistic conditions and focused on fire fighting, ventilation, searching for "victims", first aid, mapping, etc. (Conti, et al.1998).

The research efforts have resulted in improved disaster recovery training drills for mine rescue teams, fire brigades, first responders, and miners in general and the development of new technology such as new team lifelines and inflatable devices for fire suppression and personnel escape (Weiss, et al.1996; Conti and Weiss 1998; Kennedy, et al. 1991). Existing technologies were identified to help responders during exploration and recovery operations. These included various chemical light shapes, strobe lights, light vests, and laser pointers to identify team members. Most of these devices may be used to mark underground areas and certain mine materials. Also, strobe lights were used for mapping out escapeways and lasers were used to negotiate travel through smoke. Thermal imaging systems allow rescue personnel to see in darkness and through dense smoke and easily locate missing or trapped personnel and heated areas. A hands-free communication system showed potential for enhanced communications between team members, the fresh air base, and command center.

This paper focuses on the importance of early warning to alert all underground personnel of an emergency event and looks at devices that may assist personnel during their escape from smoke-filled passageways. The various technological devices used by the emergency responders during the training simulations are discussed. It concentrates on technology that can assist responders during exploration and recovery operations (Conti, et al. 1999). For example, through the earth signaling and effective communications, identifying personnel and materials in smoke, lifelines for escape, vision enhancement and inflatable devices.

THROUGH THE EARTH SIGNALING AND COMMUNICATIONS

It is imperative during an underground emergency that all personnel, no matter where their location is, can be notified of the event. The LLL has installed such a device, a wireless signaling system that transmits an emergency warning, which can quickly reach every underground miner. The low-frequency electromagnetic field can penetrate kilometers of soil and rock to reach the most remote shaft or tunnel, which makes it ideal for underground signaling and paging. This system consists of a low-frequency transmitter that can be strategically placed to create an electromagnetic signal that can completely envelop most mines without the use of repeater systems. The transmitter loop antenna is on the surface, and a receiver/transmitter loop antenna is underground. The person-wearable receivers are small, lightweight modules incorporated into the miner's cap lamp assembly. Signals can be directed to an individual, to a group, or to all underground/surface personnel. Fire brigades and mine rescue teams could be alerted, and key personnel contacted. Upon receiving an emergency or paging signal, the cap lamp begins to flash, which in turn alerts the miner to evacuate the mine or call the surface for a message, depending on which signal is received. The system can also turn devices such as strobe lights on or off to identify escape routes. Additional information on wireless signaling systems and medium frequency radio communication systems for mine rescue can be found in (Conti and Yewen 1997; Dobroski and Stolarczyk 1982).

A successful evacuation of miners during the Willow Creek mine fire, that occurred in Helper, Utah, on November 25, 1998, was attributed to a similar system, the Personal Emergency Device (PED)[1] (Zamel 1990). This system displays a message on a LCD display after the cap lamp flashes. The paging system was activated when one miner saw flames and telephoned the dispatcher to evacuate the mine. The PED system allowed a mine-evacuation plan to be safely carried out before the mine passageways filled with smoke. All 46 underground miners escaped in approximately 45 minutes. There are currently 17 PED systems installed in U.S. coalmines and one in a metal/nonmetal mine.

Transtek Corp has developed a wireless, two-way cellular communications system for underground mines (Product and Process News). The ComCell technology can be used to reduce communications costs and improve underground productivity. They are also testing a unique Through the Earth wireless system that allows two-way mobile voice and data communications between the underground passageways and above ground sites. There are currently 2 systems installed in underground facilities.

Communication is a major issue and concern of rescue teams. Team members are often unable to hear other members, and at times the communication signal to the fresh air base is also faulty. This

[1] Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health

can be very frustrating to team members, especially in high stress situations. The sound powered communication/lifeline system, developed in 1946 by the former U.S. Bureau of Mines, is the most typical system in use today. Although this type of system tends to be reliable, it does have problems. It requires the use of large cable reels (304-m of cable) and the communication often gets scrambled as the electrical contacts in the cable reel wear. Also, good electrical connection to and along the lifeline cable is necessary. The current practice is that the tail person, who has the earphones and microphone, talks to the fresh air base.

To address the communication concerns of mine rescue teams, several devices and systems were looked into (Conti and Chasko 2000). For example the m-Comm communications system, developed in the United Kingdom, shows merit for improved communications for emergency responders. This system is intrinsically safe and designed specifically for confined space and rescue applications. It consists of a single (lightweight) wire on a dispenser reel holder, that is payed out on entering the area to be explored, three handsets, and a portable base unit. The handsets receive and transmit from any point along the guide wire. It has a range of 8-Km and the guide wire could be deployed from the fresh air base to the surface command center.

Other devices such as the Voiceducer and or "head-contact microphone" maybe used if the mine had a radiating transmission line or if the lifeline was also antenna. The Voiceducer, combined with a two-way radio, provides hands free two-way communications from a small device worn in the ear. Although it looks like an ordinary earphone, the earpiece contains both an accelerometer microphone and a miniature receiver component. The "head-contact microphone" is a hands-free radio microphone that can either be strapped onto the forehead or incorporated into a helmet headband. Rescue members need not to speak into this microphone; it gathers sounds from vibrations transmitted through the skull and works whether the rescue member is wearing an SCBA or not. Additional research is underway to improve mine rescue communications.

IDENTIFYING PERSONNEL, MATERIALS AND ESCAPE ROUTES

NIOSH attempted to address several issues raised by rescue team members that participated in the simulations. One of the main concerns of the rescue teams was identifying other team members and marking locations, such as crosscuts, brattice curtain, cribbing, and other items that may be found in the smoke-filled entries, or just maintaining a reference point. Chemical lightshapes (lightstick, light rope and light disc), a technology that has been around for years, were found to be a valuable tool for underground rescue teams. The lightshapes are nonflammable and not a source of ignition, and they are weatherproof, maintenance free, and nontoxic. To activate, just remove a lightshape from the package, bend, snap, and shake. Instantly, a source of light exists that can vary in intensity and duration. The brightest lightstick lasts 5-min and the least brightest, 12-hrs. The brightest lightstick is an excellent source of light to administer first aid in smoky environments. Team members assessed the cylindrical lightsticks during the simulations, both in white nontoxic smoke and black toxic smoke produced from conveyor-belt

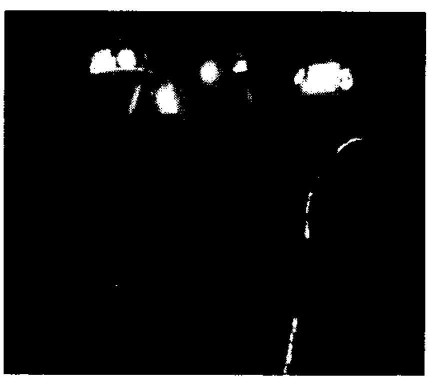

Figure 1. Chemical lightsticks attached to the back of miners

fires. Four lightstick colors were evaluated; clear, green, red, and yellow. Team members, as shown in figure 1, attached these lightsticks to the back of their helmets with plastic ties. They can be also placed on the floor at various critical locations and on obstacles during exploration or may be used to mark supplies and materials. The team member, whose duties require mapping the passageways, can use a lightstick to illuminate the map board. Of 403 members participating in the white nontoxic smoke training simulations, 80 pct-identified green as the most dominant color seen and the least visible color was clear. Out of the 90 rescue team members that participated in fighting the conveyor-belt fire, 85 pct felt that green was the most dominant color; red was the least visible color. Lightsticks are an important component for some mine rescue teams.

Team members also evaluated other lightshapes. Lightropes were mounted around the brim of the helmet, and circular lightdiscs were mounted on the back of the self-contained breathing-apparatuses (SCBA's). The lightdisc was helpful, however, the lightrope was found to be ineffective.

In other smoke training exercises, the lightstick was effectively used to negotiate travel through a smoke-filled passageway. The participants turned off their caplamp and held a green lightstick out in front of them, about waist high. Some miners have started storing lightsticks in their lunch buckets or having them in their possession for emergency use.

Personnel working around moving equipment in low light areas are always placed at risk due to their poor visibility to the operator. The light vest is a technology, developed by LiveWire Enterprises, Inc., that uses a blue/green or orange electroluminescent fiber and a 0.5-mm copper wire coated with a semiconductor material. It is safe, non-toxic, flexible, impact and water resistant, portable and produces no heat. An AC or DC power source is used depending upon its length; and current consumption is as low as 0.3 mA/m. Two AA batteries could power the vest for over 24-hrs. The light vests were modified with Velcro straps to wrap around a mine rescue member, including their SCBA, for 360 degree visibility. Team members felt that it was much easier to see other team members, who were wearing the light vest, in darkness and in smoky entries. Several mines are also considering the use of light vests for personnel working around moving machinery.

Another area examined was utilizing high-intensity strobe lights (xenon-white flash tube) strategically located in the entries to map out an escape route for evacuating miners during an emergency. They were also used to mark materials (fire hydrants, cribbing, etc.) in the smoky passageways. These weather resistant strobe lights, with interchangeable reflective lenses, are compact and lightweight and provide visibility of 180°. The triangular shaped, lithium AA battery powered strobe lights could be remotely activated by a wireless through-the-earth signaling system such as the one installed at LLL. Ideally, underground sensors would monitor the gases and smoke in the passageways during a fire. By interfacing these data with a computer, the best escape route could be determined and the appropriate strobe lights remotely turned on.

During in-mine rescue team simulations conducted at LLL, strobe lights were positioned in the center of the entry about 1.8-m from the floor and in the entry crosscuts predetermined to be the best escape routes. The strobe lights were activated by the wireless, through the earth signaling system. Rescue team members were told that a roof fall had occurred and severed the main communication/lifeline. Team members detached themselves from the main communication/lifeline and successfully followed the strobe lights out of the smoke-filled entries to the fresh air base. Team members felt that by keeping their cap lamps off, the strobe lights were easier to follow. Two hundred and seventy-one miners evaluated five strobe light colors (red, green, blue, amber, and clear) during the simulations. The most visible color in the nontoxic white smoke was green and the least visible color was amber.

A similar simulation was conducted for underground mine personnel in a Western mine. Miners, in groups of five, entered smoke-filled (nontoxic white smoke) passageways and followed strobe lights to the fresh air base. Not only did this exercise allow miners to travel through smoke in their mine (many for the very first time), but also it gave them an opportunity to evaluate the strobe lights as an escape aid. Miners felt that placement of strobe lights at decision points was quite helpful and interfacing these devices with an audio output would enhance the use of strobe lights for mapping escapeways. The miners felt that the colored reflectors currently mounted in the center of their entries would not have helped them.

The concept of strobe lights to identify escapeways and marking mine obstacles was successful in experiments at the Lake Lynn Mine and several isolated passageways of a Western mine. In a larger mine, the uncertainties inherent in a complex ventilation system would complicate this process considerably. Additional research would be required to evaluate the feasibility of using these devices in larger mines and incorporating audio output with each strobe light unit.

Another successful device that was evaluated in smoky environments uses laser technology. Commercial laser pointers are compact, lightweight, affordable, and have high quality beams. They utilize laser diode technology and several of these handheld battery powered pointers have ranges of up to 732-m. Rescue team members' evaluated two class IIIa laser pointers, red and green. The red laser pointer, with a wavelength of 645 nm and output power of 3-5 mW, can operate continuously for 8 hours. The green laser pointer, with a wavelength of 532 nm and an output power of 1-3 mW, can operate continuously for 2-3 hours. The green wavelength appears brightest to the eye, so a high power is not required. Beam diameters are less than 1-mm.

The team captain is fitted with the green laser and the tailperson with the red laser. These pointers are mounted to their cap lamps with hose clamps. The laser beams were highly effective in the smoke-filled entries, allowing team members to easily determine the location of the captain and tailperson and to stay in better alignment across the entry during exploration.

During smoke training exercises, the laser pointer was effectively used to negotiate travel through a smoke-filled passageway. Approximately 25 participants during each exercise traveled 300-m in a nontoxic smoke-filled entry, using a lifeline to lead them to fresh air. Visibility ranged from 0.3 to 0.9-m and there were no tripping hazards in the entry. Two to three participants entered the smoky entry at 40 to 60-sec intervals, until all participants were headed toward the fresh air base. Another participant followed this group with only the laser pointer to direct them to the other end (no lifeline) and with their cap lamp turned off. The beam of the laser pointer was continuously moved up and down and left to right. When the beam hit the rib, roof, floor, or other participants, a spot was seen. The participant with the laser reached the fresh air base at the same time as the first participant who entered the smoke. The concept of laser pointers was successful in experiments at the LLL and operating mines. Additional research would be required to evaluate the feasibility of using higher power lasers to identify escape routes in smoke-filled entries or surface structures.

Everyone realizes the problem encountered while driving an automobile in foggy conditions at night with high beam headlights on. The same problem is experienced in smoke-filled passageways both by miners attempting to escape and also by rescue personnel. During several training simulations in nontoxic smoke, a colored lens filter was placed over the cap lamps of 121 miners in an attempt to reduce the glare from the white light reflecting off the smoke particles. The color filters that were evaluated included green, blue, orange, and red. Green was the most visible color seen by 38 pct of the miners. Seventy-one pct of the miners felt the lens filters were useful in reducing the glare from the white light and beneficial in traveling through smoke. It has also been suggested that a miners cap lamp can be taken off the helmet and held about waist high to negotiate travel through smoke.

LINKLINES AND LIFELINES

When searching for missing personnel or exploring a hazardous smoke-filled environment in underground mines, rescue team members are attached to a team lifeline or linkline. This team lifeline is then connected to the main communication/lifeline that extends from the team lifeline to the fresh air base. Usually, five team members are fixed along the 8.5-m length of rope, at various distances between the captain (lead person) and tail-person. Team members have reported that if one person would trip and fall, other team members would be pulled down with the falling team member. If the rope became entangled around obstacles, finding it was difficult.

These concerns were solved by the development of a lighted team lifeline (Conti and Chasko 2000). Four different colored flexible light wires (Live Wire technology, 0.5-mm copper wire coated with semiconductor material) connected in series, pass through a 0.6.4-mm diameter hollow-single braided polypropylene rope (336 kg tensile strength) and has 360-degree visibility. The light wire is battery powered and will last a minimum of 4-hrs. The entire length of the braided rope is sheathed with clear polyvinyl chloride tubing. Double-locking snaps and D-shaped carabineers are attached to both ends of the rope for the captain and tailperson, with three moveable snaps and carabineers in-between both ends for the remaining team members. Team members attach the carabineers to their mine belt and have freedom of movement to slide between the captain and tail-person, providing flexibility of motion to do activities such as carry supplies, erect temporary ventilation controls and construct roof supports. This also alleviates tripping and falling problems. The different colored light wires allow the team members to easily find their usual position along the lifeline when exploring in darkness and smoke-filled passageways.

Typically, during exploration at underground intersections in smoky conditions, the tailperson is anchored to a corner of a crosscut, while the team members explore the intersection and the captain locates the opposite corner. Most of the time, the team is restricted by the length of the 8.5-m linkline, and would swing back around to the tailperson, missing the opposite corner and causing delays. During the training simulation, two of the rescue teams evaluated the use of a retractable line (6.1-m in length) in addition to the linkline. This new concept greatly reduced the time that team members explored the intersection, because the captain is able to add extra length to the linkline during exploration in intersections.

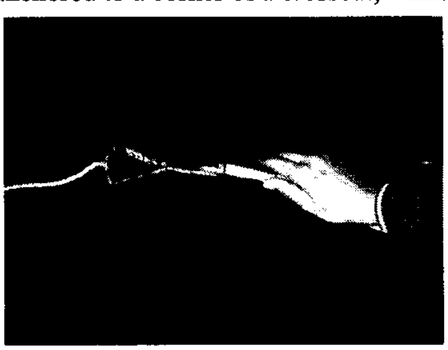

Figure 2. Continuous lifeline for escape.

Underground mines mark their escapeways with reflectors or arrows. Usually two colors are used to represent primary and secondary escapeways. After a period of time, the dust entrained in the airways can collect on the reflectors and decrease their effectiveness, so they may never be seen if the passageways are filled with smoke. A few underground mines use a continuous lifeline for escape purposes. This lifeline or rope would most likely be secured to the rib of the mine starting at the working section and leading to the exiting portal. Some mines are securing the lifeline near the roof in the center of the entry, at an average height of 2-m from the floor, and lower in lower seam mines. Depending on the configuration of the mine, the lifeline could be many kilometers in length. One manufacturer developed a directional lifeline shown in figure 2. It consists of standard spools containing 91-m of 0.64-cm polypropylene rope with directional (cone-shaped) orange indicators with green reflective tape installed at every 23-m interval. The tapered end of the cone should always point inby, so that escaping miners would never have to take their hand off the line. Due to the complexity of mine entries that contain crosscuts, mandoors, overcasts, etc., it is suggested that two directional indicators be mounted together on the lifeline approximately 2 to 3-m from a mandoor, etc. This procedure would alert personnel escaping in smoke-filled entries that an obstacle of some sort is nearby.

A study is currently underway to evaluate the feasibility of using prototype pinwheels to identify primary and secondary escapeways. The pinwheels are constructed from durable and highly reflective Scotchlite or Holographic prism materials. The four colors used, shown in figure 3, are green (Scotchlite), silver, yellow and red (Holographic prism). One side of the pinwheel facing the airflow is painted black. During the six-month evaluation in an eastern coal mine, data will be collected on dust buildup, reflectance to camp lamps and general views from the miners on preferred color, etc.

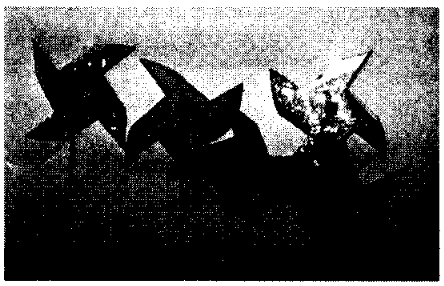

Figure 3. Prototype pinwheels to identify escapeways.

When smoke is encountered underground, visibility is reduced, anxiety levels increase and decision making skills can become clouded. It is extremely important that the miners from each section stay together and retain the necessary tools to aid them in a successful evacuation. A few mines have evacuation or escape kits on each section. An ideal kit would contain the following items: rope, lightsticks, chalk, SCSR's, first aid kit, brattice curtain, a mine map, handheld gas sensor and, depending on the mine communication system, an extra radio or pager phone. The rope is used for the crew to attach themselves to and keep everyone together, especially when traveling through smoky passageways. Various colored and intensity chemical lightsticks would be available to mark passageways, so if the crew did become disoriented and lost they would know that they had passed this way before. They can also be used as a light source to negotiate travel through smoke or the high intensity lightstick can be used when administering first aid. Chalk maybe used to mark the ribs, stoppings, etc. (names, direction, date and time). Each miner would carry extra SCSR's. A handheld gas sensor can alert the crew of hazardous gases. A pager phone or radio may be used to effectively communicate to the surface or rescue team where the crew is located or underground conditions. An updated map is essential to travel out of the section and mine to safety. Some kits also contain materials to barricade and should only be used as a last resort when all escape routes are blocked. Some mines are considering portable lasers to travel through smoke.

SEEING THROUGH THE SMOKE

Fire fighting and similar emergency response activities often impair vision due to dense smoke or darkness. Vision enhancement in such circumstances is a profound benefit for completing the assigned task. Infrared (IR) thermal imaging enhances the user's vision when visible light is inadequate. Thermal imaging both restores vision and also provides significant additional information to the user that would otherwise not be possible to obtain, for example, fire scene assessments and seeing through smoke. This technology increases the responder's understanding of the environment (fire location, problem areas like ceiling collapse, firefighters' progress in effective extinguishment, and firefighter safety), thus enhancing safety and the ability to accomplish the task.

The thermal imaging camera was developed in the early 1970's. Over the last decade, the thermal imaging camera has become an invaluable tool for emergency responders and fire assessment. It is very different than the common night vision device that either amplifies available light or senses reflected near IR energy. Thermal imaging cameras utilize infrared detectors that incorporate special materials that provide an electronic signal proportional to the amount of detected radiant energy. The latest technology being used is a non-contact sensor called a "micro-bolometer." The bolometer is a device that actually changes temperature proportional to the amount of radiant energy focused on the element. This change in temperature generates an electrical signal which when processed produces the infrared image that is seen in the viewfinder. The camera differentiates objects by their thermal temperature characteristics, and it can see through smoke, darkness and invisible flames produced by burning hydrogen or alcohol. However, it cannot see through solid objects, such as concrete and masonry, nor can it see someone directly behind the flames. Shiny surfaces (bodies of water, glass, stainless steel) reflect IR just as they reflect visible light.

Recent improvements in the sensitivity and resolution of uncooled IR imaging sensors have provided the major enabling technology for the development of a practical helmet-mounted IR vision system (Miller 1997). In 1995, Cairns & Brother Inc. introduced the first commercially available hands-free helmet-mounted IR imaging systems. Firefighters can use the Cairns IRIS to see through dense smoke and darkness in structural fires allowing a faster and more effective "size-up" of the situation. The system processes the signal and displays a black and white image that shows the hottest areas as white, the coldest as black and the temperatures between as varying shades of gray. It can detect 0.3 °C differences in temperatures. The sensor is a specially coated 15-mm Germanium lens that filters out everything except 8 to14-micron infrared radiation. The helmet-mounted IR imaging system weighs 4.8 kg. A rechargeable nickel cadmium battery pack provides 30-min of continuous, uninterrupted use at ambient temperature.

The first demonstration of the Cairns IRIS in an underground mine was conducted at Lake Lynn Laboratory on February 8, 1996 (Conti et al.1998). The capabilities of the hands-free thermal imaging camera in the smoke-filled mine passageways suggested that it indeed had merit for reducing the time required for mine rescue exploration. However, the training simulations indicated that new protocols need to be developed when mine rescue teams explore with these IR devices, because the team member with the thermal imaging camera (TIC) can travel smoke-filled entries much more rapidly than other team members (Conti et al.1999). One recommendation would be to have a retractable line attached to the person using the TIC. This way, the rescue team can still go about exploring and mapping, while the member with the TIC, still attached to the team, can examine the thermal image more closely and report to the team. A drawback of the Cairns Iris is the weight of the helmet-mounted system; the system cannot easily be passed on to other team members and could not be used in low coal mine seams. Cairns IRIS recently introduced the Cairns-Viper, a hand-held thermal imager. It offers superior image quality, and the innovative, 180-degree-rotating display provides comfortable viewing from any position. It enables the user to see from 0.9-m to infinity.

The Agema 550 System is a high-performance handheld IR camera. It has digital voice recordings, color images, and storage capabilities. The spectral range is 3.6 to 5.0-microns and it weighs 2 kg. It can easily be passed on to other team members or a small display can be added to the camera for all team members to view. The major advantage is that the thermal image can be downloaded to a computer for analysis or interfaced directly to a monitor for debriefing members at the fresh air base or command center so that key personnel can view thermal images of the event. IR cameras may also be used for preventative measures, such as to fire boss underground areas prone to fires, for example, belt drives, power centers and areas susceptible to spontaneous combustion. They also could be used to monitor welding and cutting operations.

A Flir System called FireFLIR, is used in conjunction with SCBA's (other TIC's can also be used this way) and is easily attached to the underside brim of most standard firefighting helmets for hands-free operations. It is a completely self-contained viewing apparatus with no external cables or components to catch or to impair movement. The spectral range is 8 to14-microns. The device weighs less than 2 kg and images can be viewed in either black and white or color. Advanced optics and display offer natural depth perception and orientation. It is also designed to easily view both IR and normal visual modes without moving the TIC. The FireFLIR is quickly and easily handed off to other team members. Rescue teams that had an opportunity to evaluate the various thermal imaging cameras during training simulations preferred this TIC, due to it's light weight, viewing and carrying capabilities and ease in transfer to other team members.

The Argus Thermal Imaging Camera can also see through smoke and darkness. Its spectral range is 8 to14-microns. It is ergonomically designed for comfort and utility, is handheld, and has an angled viewfinder. Moreover, this TIC accommodates a variety of users' positions from standing to lying prone. In low coal exploration, the innovative design reduces potential neck strain and, when used in a stooping position, helps to prevent the back of the helmet from hitting the SCBA, which can occur with the helmet-mounted version. It can easily be passed on to other team members for viewing the thermal image. Argus recently introduced the next generation camera (Evolution 4000), shown in figure 4. It features a remote wireless video transmission system, high-definition big screen display and a heat seeker indicator system. The heat seeker displays red attributes on the black-and-white display for immediate identification of the seat of the fire when the temperature reaches 200 °C.

Figure 4. Rescue team member using a thermal imaging camera.

During experimental tests at LLL, the video signal from the camera was successfully transmitted from inside a metal and concrete block fire gallery to an outside remote receiver station. The remote receiver, located 60-m away, was positioned in the direct line of sight to the camera. In the underground tests, the video signal was transmitted from the exploring mine rescue team to the fresh air base (FAB). The remote receiver, located 200-m away, was in the direct line of sight with the camera. Command center or fresh air base personnel could use this feature to better direct rescue and firefighting efforts.

During advanced training exercises, mine rescue teams and fire brigade members used a TIC during a training application while extinguishing a conveyor-belt fire in the Lake Lynn fire gallery. The rollback smoke was so thick and sooty that as the team members entered the fire gallery they could not see their hands in front of their facepiece. The person using the TIC was able to view the flaming belt, the hot rollback smoke and gases at the roof, and the team members as they entered the gallery. This person was in a better position to direct the firefighting efforts of the team. When two waterhoses were activated in the fog stream, the water spray immediately cooled the area, thus allowing the teams to manage the rollback smoke as they advanced towards the fire to extinguish the flames.

Drager recently introduced the next generation FireOpTIC. This camera features color image display, instant on (30-sec for camera to begin normal operation) and remote wireless video transmission. Its spectral range is 8 to14-microns. The optional Life Sensor Software allows the operator to locate persons who may be near flames without the occurrence of "white-outs" or "black-out borders" on the display caused by viewing open flames. The automatic shutdown feature prevents unnecessary and distracting temperatures (above 104 °C) from being read and displayed thus allowing the operator to search for bodies based upon their temperatures

Seeing through infrared cameras is different than with natural vision. IR images are thermal interpretations of objects and those interpretations do not appear the same as the objects appear when you look at them with the naked eye. It is imperative that personnel using these devices be properly trained.

UNDERGROUND SMOKE TRAINING EXERCISE

To better prepare miners to escape from underground smoke-filled environments, a series of smoke training exercises were developed and evaluated by NIOSH. Objectives of the exercises were to evaluate present escape methods, existing technology, and new technology that could be used for escape purposes, while giving the miners an opportunity to travel through smoke-filled entries at their mine. A non-toxic smoke generator is used to create a smoky atmosphere and the visibility can be varied from several meters to zero. The smoke generator is also an excellent device to evaluate the smoke leakage of mine stoppings and seals or to observe air currents. At the end of each training segment, miners completed a questionnaire, which included both forced-choice and open-ended questions, such as demographics (age, mining experiences, special training, etc), anxiety levels, usefulness of the exercise and technology, most visible colors seen in smoke, and underground firefighting experience.

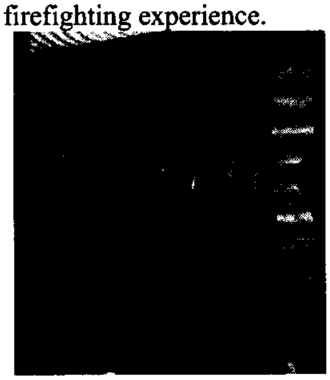

Figure 5. Underground smoke training exercise.

One hundred twenty-seven miners participated in a smoke training exercise in a Western underground coal mine. The average age of the participant was 37.3 years and average number of mining experience years was 12.5. Miners in groups of five, shown in figure 5, traversed more than 300-m of mine passageways filled with nontoxic smoke. Visibility ranged from 0.5 to 3-m. Various devices were mounted on the roof in the center of the entry, placed on the floor or secured to the rib and worn by miners. Of all the devices (chemical light shapes, strobe lights, laser lights, light vests, cap lamp, reflective materials, thermal camera, lifeline, other) evaluated in the nontoxic smoke, miners felt that the two most beneficial devices for identifying other people in smoky passageways are light vests and lasers. These miners also felt that the lasers and lifelines were most beneficial in leading you to safety and/or out of the mine. Some of the miners were concerned about the durability of lifelines during fires, explosions, and roof falls. When asked about their views on thermal imaging cameras or see-through-smoke devices, they felt that this technology would not apply to escape. This was mainly due to the cost of thermal imaging cameras. However, they realized the importance of using this technology for rescue and recovery operations and felt that every mine rescue team or fire brigade should have access to one. Fifty-six percent of the miners that participated in the training reported that they have traveled through smoke at some time in their mining career.

An important consideration in any fire safety program is adequate hands-on training for the entire workforce (first, second and sustained responders). Quality training (Conti 2001) enhances the awareness of mine fire hazards and promotes self-confidence. One of the strong points of the underground smoke training exercise was that miners felt they were better prepared for a real life situation. It gave them a first hand look at what they could be up against by training in nontoxic smoke. They also felt that it gave them a unique opportunity to evaluate devices that can help them navigate through smoke-filled environments.

INFLATABLE DEVICES FOR FIRE SUPPRESSION AND PERSONNEL ESCAPE

When mine fires can no longer be fought directly due to heat, smoke or hazardous roof conditions, high expansion foam (HEF) may be one way to remotely quench the fire. The firefighters and HEF generator can be located away from the immediate vicinity of the fire at a less hazardous underground location. The HEF is a convenient means of conveying water to a fire. It quenches or extinguishes a fire by diluting the oxygen concentration through the production of steam, blocking the air currents to the fire, and blocking the radiant energy from the fuel to other combustibles (Conti 1994; Havener 1975; Nagy et al. 1960).

To effectively use the foam method for remotely fighting fires in underground mine entries, it is often necessary to construct, at some distance from the fire site, a partition or stopping in fresh air to separate the foam generator and its operators from the smoke and toxic fire products. If this is not done, the HEF could flow back over the foam generator, rendering the fire attack futile. This problem is especially acute when the fire is found uphill in a sloping entry. Concrete block, wood, plastic sheeting, mine brattice cloth, or similar materials have been used for such partitions. Often, mine entries have irregular dimensions to which the partition must conform to avoid leakage around the periphery. Construction of such partitions can be a time-consuming process. After the partition is constructed, a hole must be cut through it to allow passage of the high expansion foam from the foam generator to the fire site. During a recent underground simulation for mine rescue teams and fire brigades in an operating coal mine, it required well over an hour to construct a partition from wood, metal and brattice curtain, and start the foam propagating up the mine entry.

To address the drawbacks of constructing a partition for HEF generators, the inflatable feed-tube partition (IFTP) (Conti 1994; Conti and Lazzara 1995) was developed. The IFTP is a lightweight, inflatable rectangular bag. The device can rapidly block large openings (within 15-min), such as those in underground mines, and simultaneously provide a feed-tube for high expansion foam. This allows firefighting foam to freely flow to the fire site and control or extinguish the fire.

The portable IFTP can be easily transported to a mine passageway leading to a fire area and then be inflated by a permissible fan/air blower, a compressed air line or an inert gas source (air or inert gas sources must be kept on to compensate for leakage). The IFTP is made from a water and heat resistant, lightweight fabric, such as chemically treated, rip-stop nylon. The IFTP could also be fabricated from a material such as Mylar or fire-resistant materials. The shape and size of the IFTP depend on the passageway dimensions in which it may be used. Additional information on the use of foam, partitions and other inerting methods can be found in the following references (Mitchell 1996; Conti 1995; Conti et al. 1997; Bird et al. 1999)

Another conceptual use of an inflatable bag is a positive-pressure, inflatable walk-through escape device (IED). This rapidly deployed device, with its "pass-through" feature, allows extra time for personnel evacuation by isolating a smoke-filled entry from fresh air. The IED would be strategically placed in a mine entry, and then be either manually or remotely deployed during a mine fire. Evacuating miners would enter the IED from the smoke-filled entry and exit into the fresh airside.

To better maintain inflation when the IED doorways are opened, a third generation positive pressure, inflatable escape device was fabricated and successfully evaluated in the Lake Lynn Experimental Mine. The unit is a rectangular bag constructed from a heat resistant lightweight fabric and is inflated by two fans, one of which is connected to an integral fabric tubing air distribution system. The IED can also be inflated by compressed air. Large C-shaped zippered doorways on both sides of the IED allow easy entry and exit. Because the bag is under positive pressure, it is impervious to outside contaminants, such as smoke, if the air intake remains in fresh air. During a mine fire, the IED would be rapidly deployed to temporarily isolate a smoke-filled entry from fresh air. If the inflating air was clean compressed air, the bag could be used as a temporary shelter (Conti et al 1997; Baldwin 1996). The use of a fan for inflation, however, would require that the fan remain in fresh air or that filters be installed on the fan to cleanse the mine air of any contaminants. Mine rescue teams could also use the IED as an airlock system during rescue and recovery operations and it could be rapidly advanced as mine recovery progressed. For this application, an inert gas source could be used to inflate the IED if necessary. The performance of the third generation IED was assessed during mine rescue team training simulations conducted in the Lake Lynn Experimental Mine. The IED was deployed in 5 to 10 minutes and isolated a smoke-filled passageway from the fresh air base. Fully equipped five to seven member mine rescue teams can enter or exit the IED without deflating the unit. The IED has been successfully demonstrated at numerous Open Industry Briefings on Mine Fire Preparedness held at Lake Lynn Laboratory and operating coalmines. Briefing participants and miners walked down a non-toxic smoke-filled entry and passed through the IED to reach fresh air. This device successfully isolated smoke-filled entries from fresh air, and mine personnel effectively passed through the device to the fresh air base or back into the smoke-filled entries.

SUMMARY

This cooperative research effort between NIOSH, state agencies, and mining companies offered an excellent opportunity to provide realistic training to mine rescue teams, fire brigades, first responders, and miners in general, and to evaluate new and existing technology that may be used for underground mine emergencies. For example, rescue teams have identified green as the most visible colored lightshape in both white and black smoke. Some teams have now added chemical lightshapes to their cache of rescue team supplies.

Strobe lights were useful for mapping out an escape route for evacuating miners. Activation of the strobe lights by the wireless, through the earth signaling system was successful. Additional research would be required to evaluate the feasibility of using these devices in larger mines and to incorporate audio output with each strobe light unit.

During smoke training exercises, red and green laser pointers were effectively used to negotiate travel through smoke-filled passageways. The green laser pointer was the most visible color seen in white smoke. These realistic training exercises offered the workforce an excellent opportunity to evaluate devices that can help them navigate through smoke-filled environments and better prepare them for real emergencies.

By using the new-lighted team lifeline, team members have freedom of movement between the captain and tail-person. They can visually see the rope, their own position and are more flexible to do activities such as carrying supplies, erecting stoppings and constructing roof supports. The team lifeline also alleviates tripping and falling problems. The electroluminescent fiber of the light vest allows team members and personnel working in darkness, smoky conditions or around moving machinery in low light areas to be seen more easily.

Escape from complex underground passageways could be improved by using a continuous lifeline. Utilizing directional cones and double cones on the lifeline would not only lead personnel escaping in smoke-filled entries in the right direction, but also alert them that an obstacle of some sort is nearby.

The m-Comm communications system shows merit for improved communications for emergency responders. Utilizing the voiceducer, with the present radiating transmission line at Lake Lynn Laboratory, has shown potential for improved wireless communications for mine rescue teams. Additional research is required to incorporate the antenna into the main lifeline.

The thermal imaging cameras have proven useful for mine rescue exploration and recovery in the smoke-filled mine passageways. However, the simulations suggested that new protocols need to be developed when mine rescue teams explore with these IR devices, because the team member with the thermal imaging camera can travel smoke-filled entries much more rapidly than other team members.

Both inflatable devices have shown merit in providing a relatively rapid method for isolation of a mine fire and use with a foam generator for fire suppression, or for personnel escape and rescue. The inflatable partition can rapidly block large openings, such as those in underground mines, and simultaneously provide a feed-tube for high expansion foam. The inflatable escape device could be used as an airlock system during exploration by mine rescue teams and could be rapidly advanced as mine recovery operations progressed.

These technological advancements can improve the state of readiness for rescue personnel and increase the chances of survival for personnel escaping from underground emergencies.

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"Enhancing Mine Emergency Response"

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Abstract

After an underground fire or explosion there is an imperative requirement to achieve escape or find refuge within the operating life of a self-rescuer and to offer immediate wayfinding assistance to the workforce. Conditions of poor visibility, together with possible disorientation, can impede rates of egress and lead to inappropriate escape responses. This paper touches upon a number of aspects of mine emergency response, reviewing self-escape issues and examining the nature and role of specific support technologies with particular note being made of life-support and low visibility wayfinding technologies. A new wayfinding technology, developed by IMC with the support of the UK Health and Safety Executive, is reported.

Introduction and Self-Escape Issues

There will always be a requirement to have rescue teams available to respond to a mine emergency. However it is argued that the greatest impact on survivability is the effectiveness of the self-escape response of the workforce in the critical minutes after an incident. Correspondingly, legislation concerned with escape and rescue from mines addresses self-escape as a high priority and emergency preparedness is a critical element of the safety management system of any mining operation [Gibson 1996, Smith 1996].

Escape strategies need to address a wide range of operational situations and scenarios, including mines with deep, distant workings, where gradients and high heat stress conditions can greatly impede evacuation. This situation is observed increasingly as mines become more capital and energy intensive, are driven deeper and operate with long travelling distances to the production areas.

Fire remains a major hazard, and in devising evacuation strategies the oxygen cost and limitations of life-support technology must be carefully examined. The legislation in a number of countries, particularly where ventilation standards are high, permit mine managers' risk assessments to be based on the use of filter type self-rescuers. This contrasts with an international trend of adopting person worn oxygen self-contained self-rescuers (SCSRs), which provide complete isolation from contaminated mine air. However the use of chemical oxygen or compressed oxygen rescuers is associated with a small or negative safety margin in terms of available wearing time and realistic training is difficult to provide. Studies of SCSR performance under actual escape conditions confirm that the effective duration of SCSRs can be notably less than the reference rating referred to in legislation. The number and capacity of SCSRs a miner may need in order to make an escape from the deepest points of a mine is still a subject of ongoing research [Kovac, 1998].

There remains a significant working lifetime probability that the workforce will have to evacuate the mine under emergency circumstances. In a survey of 7 US mines, Vaught et al [1996] identified that an average of 21% of miners had, at some time, donned a self-contained self-rescuer or filter self-rescuer in an emergency. In the South African mining industry some 609 SCSRs were activated in 39 incidents over the period 1987-1994 [Kriel et al, 1995]. For maximum effectiveness, SCSRs must be considered within an integrated escape and rescue strategy comprising components of escape routes, guidance systems, refuge bays, hazard identification and communication systems [Smith and du Plessis, 1998]. Phillips et al [1997] consider the three key elements of this strategy to comprise body worn SCSRs, the provision of permanent or semi-mobile refuge bays and some form of guidance system for use in low or zero visibility conditions. Post-incident investigations have referred to the need for improved wayfinding following fire, explosion and windblast

[McKensey 1996]. Experience of post-explosion situations has demonstrated that, whilst SCSRs and refuge bays are critical elements of any rescue strategy, conditions can be so adverse that emergency communications and the ability to orientate oneself maybe of equal importance. [SIMRAC 1995, Kriel et al 1995b, Thyer and Weyman 1997]. Kielblock and Van Rensburg [1987] suggest that maximum face to refuge bay distances should not exceed 1500 metres in high seam room and pillar workings and that this distance may need to be halved in low seam longwall operations. These distances assume good visibility. Under conditions of low or zero visibility, speed of travel is materially impaired and may be less than 25 per cent of that possible when visibility is normal. [Kriel et al 1995b]. These findings raise questions regarding how workers wearing SCSRs of limited duration can be guided to a SCSR changeover point, refuge bay or other place of safety under conditions of nil visibility. However, prior to discussing issues of orientation and wayfinding in more detail, it is useful to briefly review refuges and havens as key elements of escape strategy.

Technologies to Enhance Emergency Response
- Refuge Stations/Safe Havens

When wearing a self rescuer of any type, the ultimate distance covered may well be a function of the physiology of the wearer rather than the performance of the self rescuer. In those mines where there are long distances to a place of safety, long duration self rescuers are considered to be essential. There is an increasing trend that the Emergency Escape Plan should not be based solely on the use of self rescuers and that consideration should be given to the introduction of refuge stations where the workforce shelters in a sealed, fireproof structure, or safe havens where evacuating staff can rest and change self-rescuers. Anecdotal evidence of a recent fire event, where 100 men sheltered safely in underground refuges for 7 hours prior to being rescued confirms 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, particularly in Canadian and South African mines. In some countries, however, the provision of such facilities is a relatively new concept. There are two main types in use, with varying designs and sizes.

Permanent Refuges

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 a 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 mines, which is the situation 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 (e.g. Ontario Mines Rescue Refuge Station Guidelines, MAPAO Committee, Sept. 1990).

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 mineworkers inside. This is typical of South African coal mine refuges. An alternative approach is a dual source of compressed air, although not all mines have compressed air supplies underground 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 below, which provide a 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, whilst the designs for coal mines must also consider explosion overpressures. Oberholzer [1997] has reviewed biological and structural impacts and considers a 140 kPa overpressure withstand capability to be adequate for structures sited away from the face.

Temporary or Transportable Units

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 intervals between 36 and 185 shifts. Given the impracticality 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 workers in reaching their permanent safe haven or first aid centre. The nearest shelters are often maintained within 50-100 metres 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 is being introduced into UK coal mines in the form of semi-sealed installations, such as canopies or pressurised "tent-like" refuges, which are erected using a compressed air supply [Forster 1997]. Three safe haven designs are being examined in the UK [Evans and Forster 1999].

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 "Tommyknocker", the South African MARS (Mobile Air Rescue Station) and the Survivair-E Life Support System [Venter et al 1997]. These systems are undoubtedly useful but can be compromised by the build up 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 carbon monoxide scrubbing [Smith and du Plessis 1998]. The development and introduction of refuges or safe havens is also only useful if individuals know where the havens are located, particularly in low or zero visibility conditions. This is considered in the following section.

Technologies to Enhance Emergency Response
- Guidance Systems for Low Visibility Conditions

Current practice in many mines is to mark escape routes with reflective signs and symbols. However these signs have a number of limitations:

a. The signs need to be kept clean, in good condition, and up to date.

b. Frequently, mine personnel pay little attention to reflective route way markings.

c. Reflective markings are of limited value in low visibility conditions.

In response to these limitations, development of orientation and guidance systems in mines has progressed along two lines [Gouws and Phillips 1995, Weyman and Thyer 1997]:

1. Passive lifeline technologies.
2. Active electronic audio-visual guidance systems.

Whichever approach is considered it should, as far as possible, achieve the following:

- Significantly increase speed of egress.
- Be useful in conditions of extremely low visibility.
- Not present ambiguous directional information.
- Provide visual, audible and tactile cues.
- Be low cost with minimal maintenance requirements.
- Accommodate differences in mine layout, working practices, culture and language.
- Offer high integrity and preferably fail-safe operation.
- Not rely on background lighting being present.

Passive Guidance Systems

Experienced mineworkers can use appropriate structures such as conveyors, cables and rails as a lifeline in conditions of nil visibility. An alternative approach is to use dedicated lifelines which lead along travelling roadways and return escapeways, often directly to refuge bays. Having located the lifeline, the individuals must continue along the line in the appropriate direction towards safety. In an attempt to provide unambiguous direction of travel, lifelines have been designed to provide unidirectional travel or tactile directional cues. According to Weyman and Thyer [1997], there are at least five different types of lifeline in use.

The utility of installed lifelines has been tested under simulated conditions [Kriel et al 1995b]. The results showed that on average, subjects wearing SCSRs and operating in nil visibility, move at approximately 75 per cent of normal walking speed when aided by a lifeline; the corresponding figure was less than 40 per cent when using only the existing structures in the section. On balance, purpose-designed lifelines present a low cost and effective means of guidance where they can be installed.

Active Guidance Systems

In an effort to provide a more effective and general purpose means of guidance, active electronic guidance systems have been developed, which employ visible and audible signals to guide personnel. Within these systems, series of roof or rib-mounted beacons are used to emit an audible and visual signal in a cyclical routine, commencing at the working face and terminating at the refuge bay or at the store of long duration SCSRs. The cost of these systems dictates that the beacons be spaced as far apart as is judged expedient, typically at 50 metre intervals or closer where directional ambiguity is present such as at junctions. This spacing leads to only partial effectiveness of the visual signal since in dense smoke conditions the visible range may be only several metres. To respond to this limitation, the systems have a synchronised stepped tone output which provides aural direction indication and location cues for the next beacon.

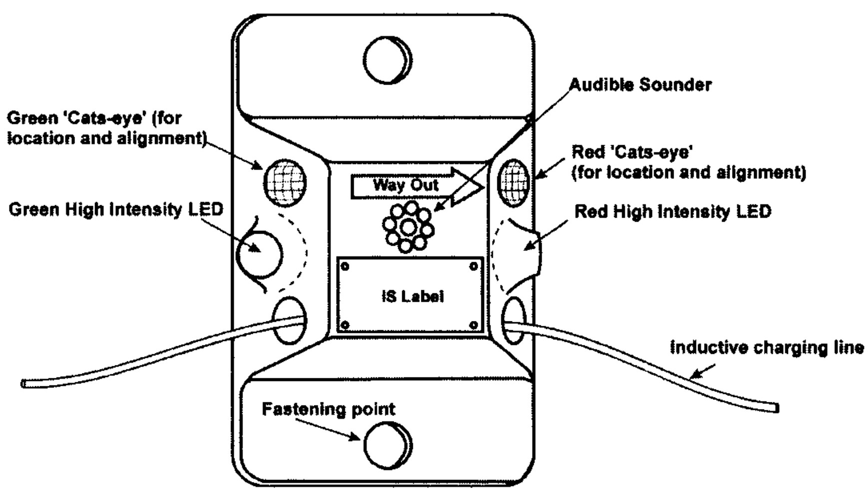
Active systems are typically mains supply operated with a battery back-up supply. The units are fail-safe and are triggered by a loss of power, or by contacts being opened manually or by means of environmental sensors. A number of systems are installed in collieries in Australia and the Republic of South Africa [Dhar 1997]. Evaluation of the South African 'Moses' system has been carried out under simulated escape conditions with nil visibility where it was found that escape time was still of the order of three times that measured under normal vision circumstances [Phillips et al 1997]. One further requirement of a guidance system is that it should show clearly where the refuge bay entrance or similar structure is located. Whatever system is used, it needs to be consistent throughout the mine and made familiar to the workforce on a regular basis.

Further approaches to assist smoke penetration using thermal imaging systems have also been proposed [Conti et al 1998] but the cost of such equipment and the lack of intrinsically safe versions suggest that their deployment in coal mine rescue or emergency evacuation situations may be limited.

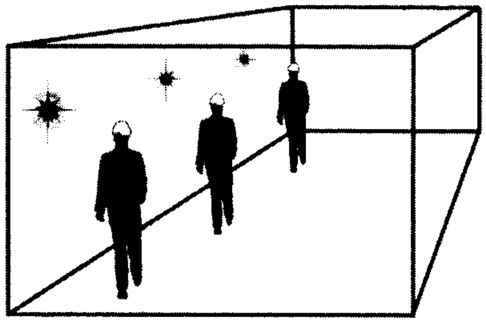
IMC's Egress Beacon System

In conjunction with the UK Health and Safety Executive and Mines Rescue Service, IMC has developed a simple but effective egress beacon system [Brenkley et al 1998]. The technical approach to the problem has involved using a sequence of bi-colour indicators and acoustic senders with a novel approach of using inductive power transfer to each beacon unit. It is feasible that the beacon system can provide a dual early warning function. The system developed by IMC is fail-safe, robust and potentially offers the lowest cost option of any 'active' wayfinding system.

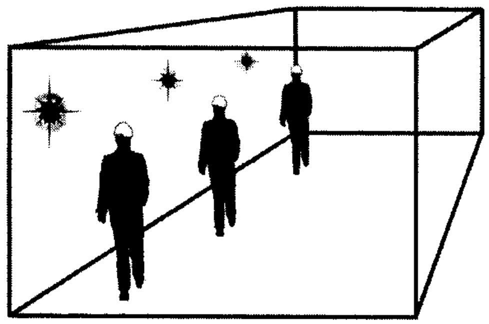
The form of the beacon is shown here in conceptual form, with the key features identified:



In principle, the scheme employs a sequence of beacons each equipped with a pair of oppositely facing red and green high intensity light emitting diodes (LEDs) together with an acoustic sender. The beacons are bolted to the tunnel wall such that when activated, each beacon presents either a red or green light, depending on the direction of travel. Where the subject is moving in the correct direction towards the egress or refuge point, then a sequence of green lights will be seen. Conversely, where the subject is heading away from the egress or refuge point then a sequence of red lights is observed. There is thus no ambiguity over the direction of travel and the system provides a powerful motivation to follow the correct sequence of lights.



Following assigned escape route

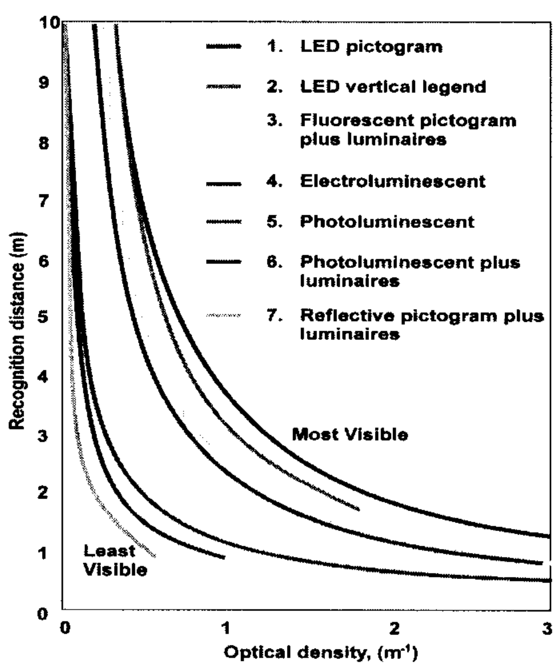


Opposite direction...

For the small percentage of the workforce with severe red-green colour blindness, visual-tactile cues in the form of a raised arrow have been applied to prototype mouldings. The direction assignment of the beacons is determined from the mine's risk assessment. Variations of the beacon have also been developed which incorporate programmable direction assignment, using low frequency inductive signalling techniques. This permits the direction of evacuation/direction to the refuge to be periodically reassigned to match changes in local requirements. The dual red-green light emitting diode arrangement can also be replaced by a single green light emitting diode to reduce beacon cost.

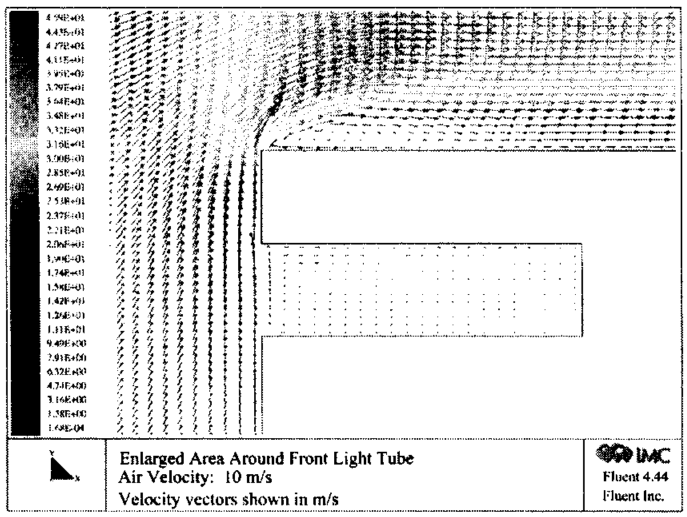
Each beacon is powered by a small internal rechargeable cell with power inductively coupled into each beacon from a charging line carrying a high frequency current. The key to the scheme is that a small but useful amount of power can be bled from the line to trickle charge the cell within each beacon. Important advantages of this approach are that the system is fail-safe, each beacon receives an identical charge current irrespective of where it is located on the line, that each beacon is totally galvanically isolated, and, any electrical failure within a beacon has no effect on the rest of the system. In practical terms, there are also significant cost and reliability benefits from not having to use multipole connectors or glanded compartments.

Tests conducted by the UK Building Research Establishment [Webber and Aizlewood 1994, Webber 1997], have shown that high intensity red and green light emitting diodes offer fair transmission through a scattering medium such as suspended smoke or dust particles. The relative visibility in smoke was observed to be higher than that of conventional signs (below). The high visibility of green and red light colours through smoke has been confirmed by Conti et al [1998].

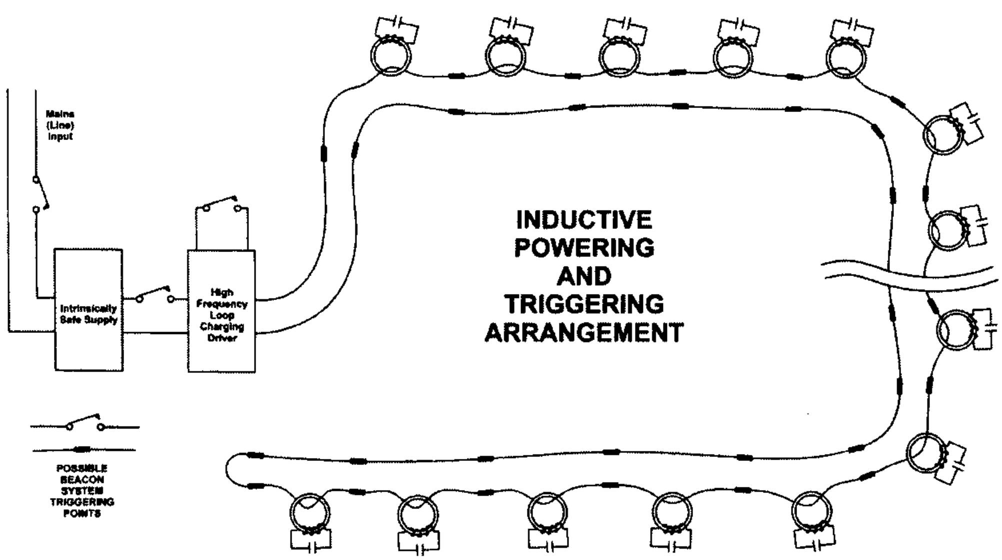


To further assist in conditions of extremely low visibility, each beacon is equipped with an acoustic resonator to provide a pulsed high frequency tone. This allows the approximate location of the next beacon to be determined even though it may not be visible.

Each beacon unit has relatively few components both to reduce cost and improve reliability. The system has been designed such that any interruption of the power supply or charging loop, whether by damage or being disconnected manually, or by an environmental monitor alarm output, will cause the beacons to automatically switch on (below). The system is thus fail-safe when subject to power loss. This also allows routine functional testing and maintenance of the network to be carried out relatively straightforwardly, since any beacons not working when the network is activated are self-revealing. In order to prevent dust build up on the optics, novel self-cleaning optical window designs have been developed. These have been shown, by the use of testing and CFD modelling, to substantially reduce dust deposition for the envisaged range of ventilation Reynolds numbers. A typical CFD plot for the optical window is shown, with stagnation in the tubular optical window resulting in only a small degree of dust entry and settlement.



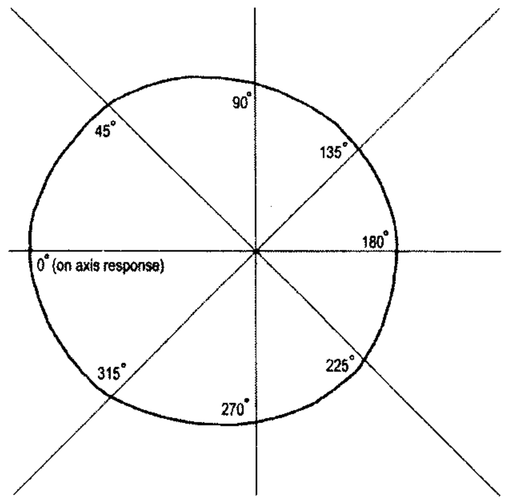
Conceptual scheme for beacon charging and triggering:



Sound Localisation of Beacon

In extreme visibility conditions, the optical penetration of any visual beacon system will reduce to the order of a few metres and sound localisation must be used to help identify the beacon direction. In the scheme proposed by IMC, a decision was made, on the grounds of cost and complexity, to dispense with the requirement for synchronised clocks between adjacent beacons. In this case the beacon acoustic arrangement must be designed such that a single sound transducer is able to provide free field localisation Auditory localisation depends on several perceptual processes, the most common cues being inter-aural amplitude differences and inter-aural time delay [Elfner and House 1987, Searle 1982].

Tests confirmed that a single sound transducer within each beacon could provide useful directional information if the high frequency directional characteristics of the transducer and the human ear were exploited. The tone frequency was selected to be around 3 kHz and various acoustic transducers were investigated for directional characteristics. Piezo-electric sounders were rejected due to their impact spark hazard. Small mylar cone transducers were selected which exhibited a high Q resonance at circa 3.0kHz, permitting a relatively high peak acoustic output from a modest drive power. The directional characteristics of the transducer were also shown to be acceptable, with an off-axis reduction of 6-7 dB(A), 18-20 dB(A) and 27 dB(A) for $\pm 45°$, $\pm 90°$and 180° respectively. A peak output level of 90 dB was observed at one metre, with an A-weighted mean of 74.5 dB(A) (reference level 2. 10^{-5} Pa). The resonators have also been successfully subjected to modest windblast overpressure testing (<5kPa peak) at IMC's Swadlincote ignition test facility.



'm-Scape'

Evacuation Beacon Acoustic Transducer

Directional Response Characteristic

(ave. measurements dBA weighted)

On-axis sound level:
89.5 dB peak
74.5 dBA mean

To exploit the directional characteristics of the transducer it is necessary that the acoustic transducer be mounted in the beacon enclosure such that it faces the same direction as the green light emitting diode. In this case, as the beacon is approached there is a progressive increase in sound intensity which drops off significantly as the beacon is passed and the next beacon is sought. Discharge tests confirmed that the beacons offer a useful operational life of approximately seven hours. This period is sufficiently long to offer assistance to both escapees and rescuers, who enter later and must be able to retrace their steps. A full beacon system has been evaluated for over 18 months in an underground gallery of the UK Mines Rescue Service at Houghton-le-Spring, County Durham. Station brigadesmen have conducted a number of tests where the galleries have been filled with smoke. In the majority of these tests, trainees were not briefed on the operation of the system but were simply told to follow the sequence of green indicators. The first-hand feedback and response from the 'escapees' is that the system is regarded as having considerable value and utility.

Observations and Current Status of Beacon Development

A number of observations can be drawn from the research and trials of the egress beacon system:

1. The concept of using high intensity red and green light emitting diodes to provide wayfinding assistance has been shown to be feasible.
2. For maximum penetration through smoke, point sources rather than planar light sources are required. Under 'heavy smoke' conditions, high luminous intensity light emitting diodes have a range of around five

metres. The visible range rapidly reduces with increasing smoke obscuration. In 'light smoke' conditions the beacons are visible beyond 15 metres or more.

3. Anticipated improvements in light emitting diode technology will permit luminous intensity to be increased by a factor of 2-3. This will increase range under heavy smoke conditions to around 8 to 10 metres or more.
4. The use of an acoustic sounder is an important aspect of providing additional directional cues in extremely low visibility conditions. Whilst a sequenced set of pulses or increasing pitch tones between adjacent beacons provides the conventional means of localisation, it is considered feasible to use a simpler approach relying on the directivity of a subject-facing acoustic sounder.
5. Intrinsically safe inductive power transfer is feasible and it is estimated that approximately 50 beacons could be attached to an IS charging line. The power delivered to each beacon battery is small, circa 5 mW maximum.
6. To address the problems of dust deposition around the beacon optics, a novel optical window design has been developed which has been shown to work well under prevailing underground ventilation conditions.
7. Compared with alternative wayfinding technologies the proposed scheme has several advantages:
    - The low cost of the beacons allows them to be more closely spaced.
    - The cost of cabling is substantially reduced.
    - Each unit is galvanically isolated and individual beacon failures have no effect on the system.

The system has been developed to a stage where it is ready for a submission of intrinsic safety. Other applications for a non IS version of the system have been identified in civil engineering tunnels.

Conclusions and Recommendations

There is an emerging recognition, world-wide, that major incidents have profound and lasting repercussions on all stakeholders involved with mining operations. This is shifting the emphasis of safety management to a proactive, risk-based approach, where effective emergency preparedness measures and emergency support provisions are key elements of reducing workplace and business risks. The organisation, systems and technologies for rescue and emergency support are reviewed by the authors in a recent IEA report [Jones, Brenkley, Burrell and Bennett, 1999].

The founding principles of any emergency escape plan 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 bays) and self-rescuers are required. The use of 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. 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.

In planning escapeways, attention has to be given to achievable escape speeds and the significant reduction expected from loss of visibility after a mine fire or explosion. In this case, nominal escape speeds of approximately 3 kilometres per hour in good visibility, may be reduced drastically. The issue of post-incident orientation and wayfinding in low or nil visibility conditions is receiving increasing attention world-wide. Mine operators and Mines Inspectorate need to be provided with best available knowledge on measured impacts and how visibility issues may be best addressed in the evacuation planning process. Both active audio-visual and passive life-line systems can offer substantial assistance under heavy smoke conditions and further reduce the risks from working in long, isolated drivages. Generic active and passive wayfinding systems have been reviewed and these offer considerable value in helping locate refuge bays in poor visibility conditions. The IMC Egress Beacon system described within the paper provides a new flexible, low cost approach to providing such wayfinding assistance. The active guidance system, which is fail-safe and utilises both visual and audible cues, offers the prospect of an intrinsically safe system with wide potential application.

Acknowledgements

The authors wish to thank their respective organisations for being granted permission to publish the paper. The views and recommendations expressed herein are personal views and do not necessarily represent the views or policies of either IMC Group Limited or Mines Rescue Service Limited.

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DOCUMENT 11

Foster-Miller
A QinetiQ Company

Guidelines for Rescue Chambers

Randy Berry
Foster-Miller Inc.

Background

- Foster-Miller is a consulting engineering company, with extensive experience in:
  - Robotics
  - Instrumentation
  - Mine safety research
    - Ventilation studies
    - Emergency escape hoist guidelines
    - Escape system guidelines for metal/nonmetal mines
    - Guidelines for oxygen self-rescuers
    - Guidelines for rescue chambers

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    - Guidelines for oxygen self-rescuers
    - Guidelines for rescue chambers

Summary of the Presentation

- Introduction
- General rescue chamber requirements
- Examples of rescue chamber designs
- Other considerations
- Location methodology
- Conclusions

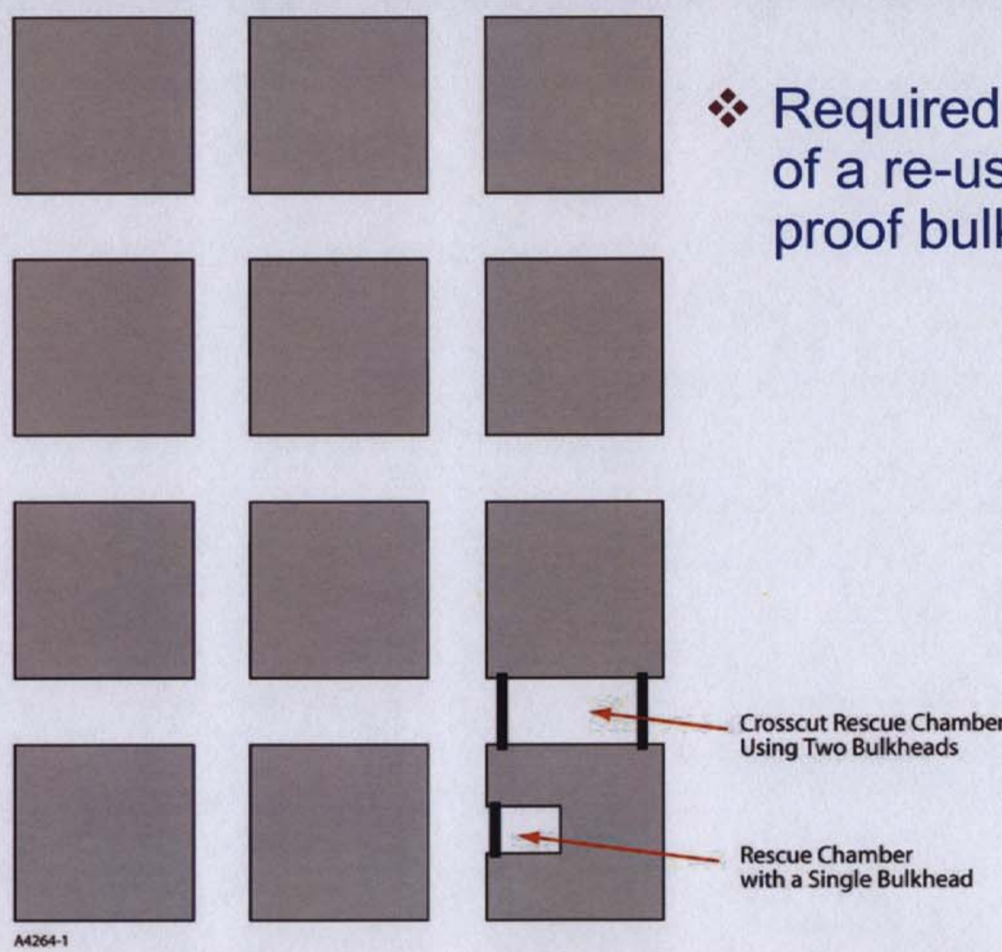
Introduction

- Rescue (refuge) chambers are a last resort option for trapped miners who have no escape options

General Rescue Chamber Requirements

- Mine specific
- Move-able and re-useable
- Explosion resistant
- Air supply
- Other considerations
  (supplies, where to locate, etc.)

Design of A Crosscut Rescue Chamber



- Required the development of a re-usable explosion-proof bulkhead

Two Part Project For Rescue Chamber Study

- Design, fabrication, and ***testing*** of explosion proof bulkhead(s) for use (and re-use) in a rescue chamber
- Development of guidelines

Key Components of An Explosion-Proof Bulkhead

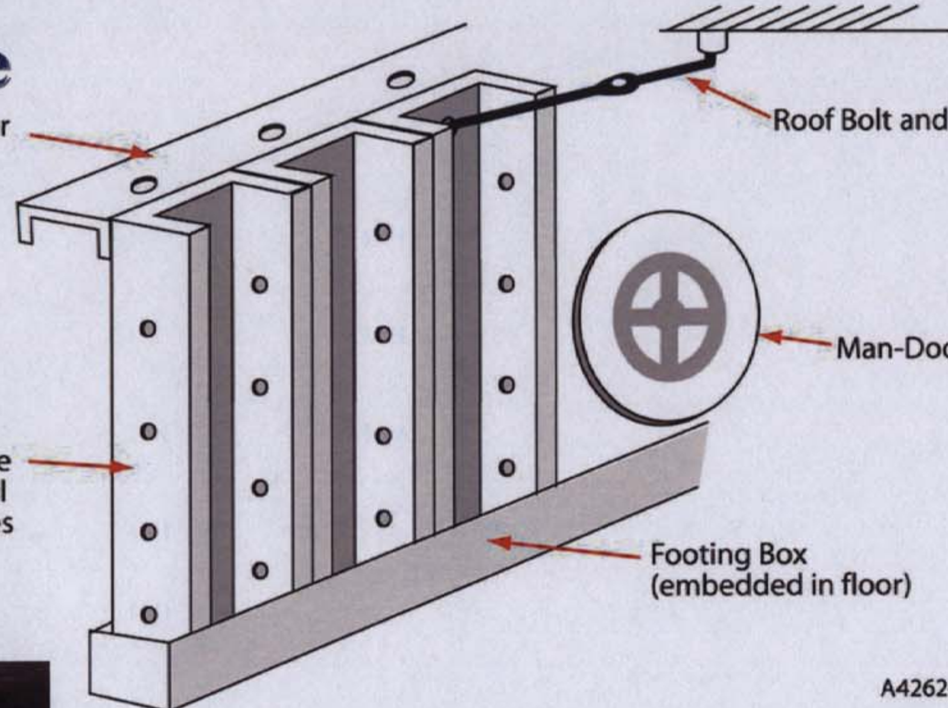
- The bulkhead
- Securing the bulkhead to ribs, roof, and floor
- Man-door
- Sealing around bulkhead perimeter

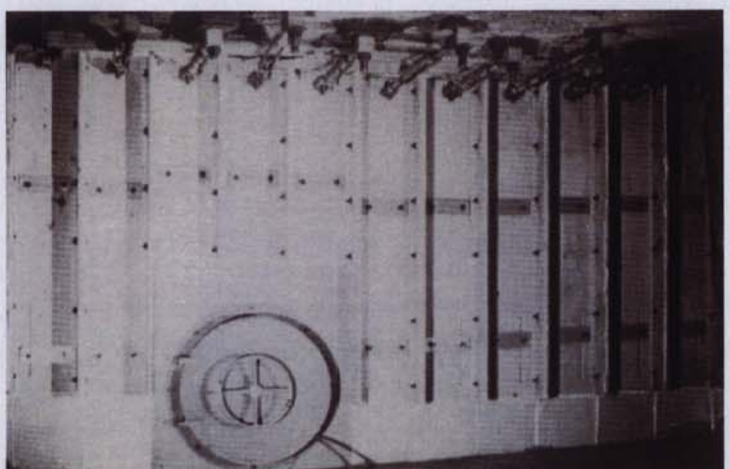
Emphasis on using off-the-shelf materials

Mine Specific Designs

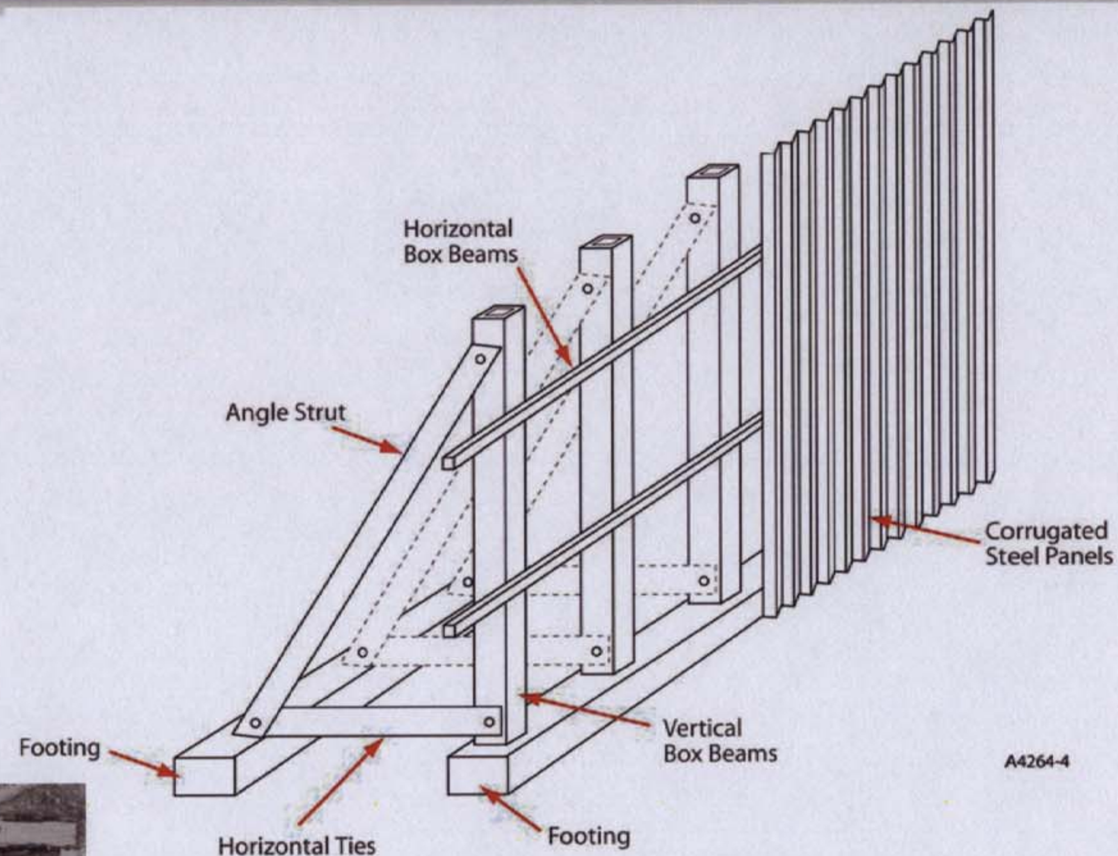
- Size of crosscut
- Competence of the surrounding strata

Design #1: Channel-Turnbuckle Bulkhead

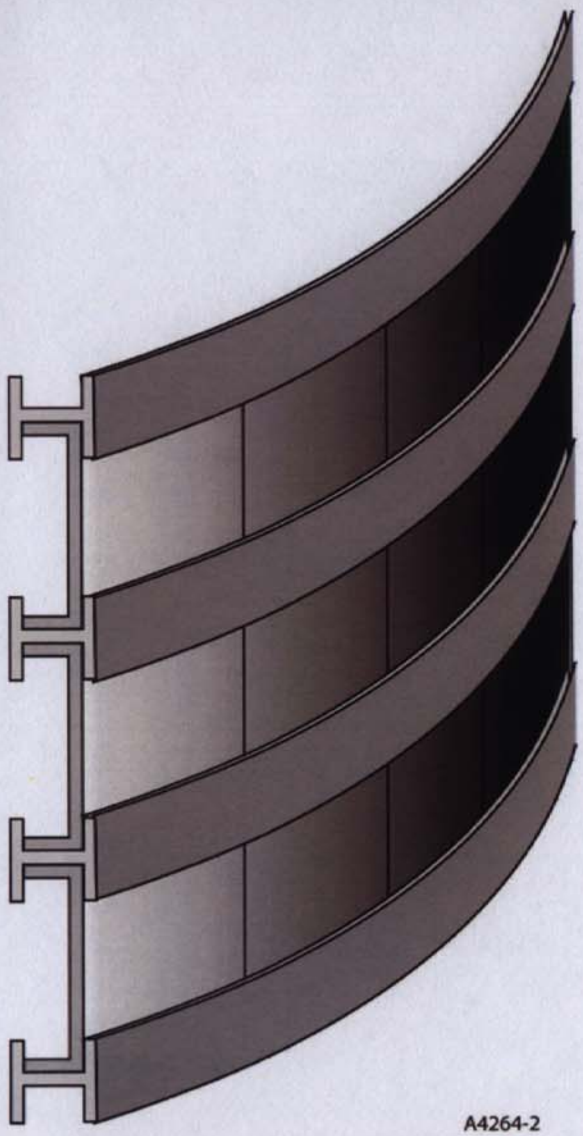




Design #2: Truss Bulkhead



Design #3: Arch Bulkhead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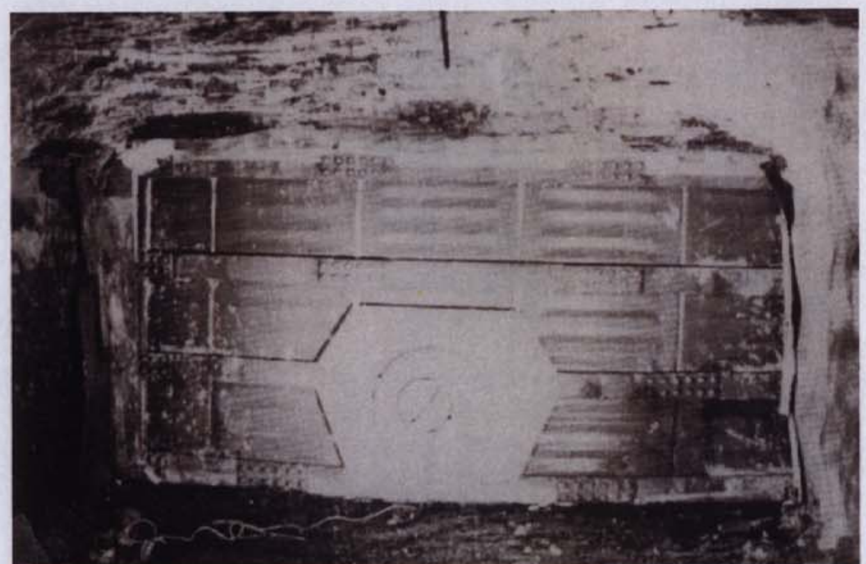

Other Considerations

- Air supply (borehole preferred)
- Food and water
- Communications
- First aid
- Maintaining roof and rib support
- Ventilation during standby periods
- Choosing location(s)

Location Methodology

- Mine specific
- Flooding risk (pumps lose power)
- Surface access
- Within 1 hour of the face
- Locations along escape routes (and to store additional SCSRs)

Conclusions

- Rescue chambers have a place in an overall mine escapeway plan
- The rescue chamber concept is worth revisiting and updating
- New technology will play a role
  - SCSRs and other emergency breathing apparatus
  - Improved structural materials (strong, lightweight)
  - Improved sealants

DOCUMENT 12

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May 17, 2006

Via Fax: 202 693 9441 and U.S. Mail
Via EM: zzMSHA-comments@dol.gov (RIN:1219-AB46)

US Department of Labor
MSHA
Office of Standards, Regulations, and Variances
1100 Wilson Blvd., Room 2350
Arlington, VA 22209-3939

Re: Standards for Refuge Chambers, Rescue Shelters and Safehouses - *Portable*

We were grateful for the opportunity to comment personally at the May 9, 2006, meeting in Charleston, West Virginia, and are now grateful to provide the following comments on the above subject:

SCSR Storage (*Cache*); *Portable* Refuge Chambers, Rescue Shelters and Safehouses

The haunting words of Sago survivor Randy McCoy "we tried to ride out (ESCAPE-my words) but were blocked by bad air" serves as a reminder that all miners have as their primary priority to *escape* a mine emergency. Those who survive the initial emergency (explosion, fire, fall, flood) deserve to be kept safe until they can be rescued or walk out.

With that in mind, research was commenced to determine, from past emergencies, what levels of protection a structure must achieve to give the miners the opportunity they deserve.

History Examined in Determining Recommendations as to Standards for Storage *Caches*, Refuge Shelters, Refuge Chambers and Safehouses (*Portable*)

I. BACKGROUND

The following appeared in the Federal Register Volume 71 No. 46 for Thursday, March 9, 2006:

> "MSHA's records show that 56 underground coal mine fires, with a duration greater than 30 minutes, and 5 explosions have been reported to MSHA during the 10-year period from February 1, 1996, to February 1, 2006. During that same period, explosions resulted in the deaths of 31 coal miners and fires resulted in two deaths. Although mine fires

that last less than 30 minutes do not have to be reported to MSHA, the agency has anecdotal reports that such fires *commonly occur*. Mine fires, ignitions and explosions, regardless of duration, can present a grave potential hazard to underground coal miners due to the thick smoke, toxic atmosphere and limited visibility that often results from these events.

In addition to reportable coal mine fires, operators have reported numerous unplanned ignitions of methane. During the ten-year period from February 1, 1996 to February 1, 2006, the Coal Mining industry reported approximately 650 ignition. Each of these ignitions have the potential result of a mine fire or explosion which would release hazardous or life threatening contaminants into the mine atmosphere.

Potentially explosive methane is naturally present in *underground coal* and can ignite when an ignition source is present. Combustible dust, including material brought into a mine, can smolder and eventually catch fire when near a source of heat. There are numerous ignition sources present underground such as belt lines, trolley wires, roof falls, diesel powered equipment, battery operated equipment, charging stations and other forms of electrical equipment are prevalent and can provide a source of ignition. In addition, coal can undergo spontaneous combustion and burn.

Underground coal mine fires reach an intensity of 1000 to 1200 degrees F."

II. FIRE and EXPLOSION Studies and Investigations

A. **Industrial Safety Division Report** - "Estimating Underground Coal Mine Fire Temperature Extremes" by Stephen J. Luzik revealed the following:

1. Underground coal fire can reach 1900 degrees F.
2. Diesel oil pan fire was studied in underground mines to be 1292 degrees F.
3. A 1952 degree F fire can cause timber burn through in 30 minutes 100 feet away and creates ignition with timbers at 755 degrees F.

B. Anecdotal evidence: FIRES

1. **BEATRICE -**

   Found a 700 degree F to (1832 degree F) fire that burned for several hours and burned timbers in a mine that had to be sealed.

2. **WILBERG -**

   Found that aluminum 160 feet downstream from the fire melted in 13 to 18 minutes. They found that at 600 degrees F the tensile strength had been reduced by 70% and by 700 degrees F it had been reduced by 90%.

Summary:

1. Fires in excess of 2000 degrees F are sometimes achieved in coal mine fires. Downstream temperatures measured at more than 1000 degrees F due to radiation and hot gas transportation.

2. Temperatures in a range of 700 to 1000 degrees F can be achieved in crosscuts or other areas of the mine remotely located from the fire.

C. Anecdotal Studies Concerning EXPLOSIONS

1. **McELROY** - An explosion with six miners working in the close vicinity of the explosion. Three were fatalities, and two were injured and one escaped with little harm. They found that the explosive force was of short duration and was 50 psi and 35 psi is a threshold pressure for fatality.

   (MSHA Investigation Report January 22, 2003)

2. **JIM WALTER MINE NO. 5** September 23, 2001 - Two (2) separate explosions with <u>32</u> miners underground resulting in <u>13</u> fatalities.

Note: At the point of the initial explosion, four miners were injured but three miners, including the Section Foreman, exited Section 4.

Second Explosion - Second Explosion at Entry No. 2 was ignited by a block light system and promulgated towards the faces of Section 4. The explosion strengthened when additional methane and coal dust became involved near the intersection of the last open crosscut in the No. 3 and 4 entries. The explosion, fueled primarily by coal dust, promulgated out by through No. 3 and 4 entries in the No. 4 east, the explosion *continued* into Section 6, Shaft 5-9 area and 3 East. The *second* explosion resulted in at least 12 fatalities and widespread destruction of ventilation controls throughout this area of the mine. NINETEEN (19) MINERS EXITED THE MINE.

Note: Explosions can only develop when proper quantities of oxygen, fuel and heat are available and when the fuel is suspended within the confined volume. The normal atmospheric concentration of oxygen occurred throughout the active mine workings and was about 20.9%. Methane only requires 12% or more oxygen to burn or ignite. Similarly, coal dust requires a minimum of 13% oxygen to burn or ignite.

3. **WILLOW CREEK MINE July 31, 2000**

A series of four explosions occurred. A roof fall in a worked-out area, a D-3 longwall panel, ignited methane resulting in the first explosion and fire. The second explosion occurred sometime thereafter and two closely spaced explosions occurred at 11:55 p.m. and 12:17 a.m. meaning that there was a primary, secondary, tertiary and even a fourth explosion. Two fatalities occurred as a result of the second and third explosion.

4. **SAGO**

Seven miners were near the explosion site. One died, six walked out.

REASONABLE STANDARDS BASED UPON STUDIES AND INVESTIGATIONS OF PREVIOUS DISASTERS

I. STRUCTURE SURVIVABILITY - TEMPERATURE

Comment: Given the previous history of: (a) temperatures ranging to 1831 degrees F (BEATRICE); (b) down stream temperatures measures at more than a 1000 degrees F due to radiation and hot gas transportation; (c) temperatures as high as 1000 degrees F achieved in crosscuts or other areas of the mine remotely located from the fire itself; and (d) steel degrading at 850 degrees F and the elevated thermal conductivity of steel and aluminum; it appears reasonable that:

A. The material for structures utilized in refuge chambers, rescue shelters, safehouses, and SCSR storage-*Caches* be made of material that can withstand heat without degrading the temperature of at least 1900 degrees F for a period of two hours without degrading or losing tensile strength. This material exists in the form of SAFETFOAM and is available at affordable prices.

II. THERMAL CONDUCTIVITY

The structure must be made of material which has little thermal conductivity in order that the heat from the exterior is not transferred to the interior creating a *crematorium* affect. For example, steel conducts heat at a rate of 420 times greater than GRAFOAM, SAFETFOAM utilized in the prototypes of the Safehouses which have been demonstrated to the Task Force and were on display at the International Symposium at Wheeling, West Virginia, April 20&21, 2006. (See attached literature)

GRAFOAM SAFETFOAM would meet these standards.

III. EXPLOSION

Comment: Given the studies of: (a) McELROY where the explosive force was measured at approximately 50 psi; and (b) the fact that underground disasters have often involved multiple explosions at varying points in time--i.e., JIM WALTER MINE NO. 5 (2 explosions); WILLOW CREEK MINE (4 explosions with each explosion many minutes apart with fatalities occurring as the result of the second and third explosions), it appears that the structure material be required to withstand 50 psi explosive force without damage to the structure. GRAFOAM SAFETFOAM has tested to 75 psi.

Mine Safehouse LLC embarked on a course to create a structure which would meet or exceed the known levels of fire and explosion from the previous studies. It did not intend to create a standard for any other purpose except to give miners a chance in the face of previous known and measured emergencies.

IV. BREATHABLE AIR

Given the experiences in terms of time to rescue trapped miners, it seems imperative that the rescue chamber, refuge shelter or safehouse:

1. Be portable - in order that the structure can move as the mining operations advance.

2. Have compressed air available.

3. Be able to provide breathable air for a period up to 72 hours and be able to supply full secondary power from batteries in the event mine power to the structure should be interrupted, and supplies by oxygen cylinder and/or oxygen candles.

4. Have CO and CO_2 scrubbers and/or self-contained units with scrubbing and oxygen generating capacity.

5. The maps be changed as the structures move so the location can be pinpointed at all times for rescue purposes.

6. Be equipped with additional SCSRs.

7. Be equipped with UPS Battery backup for scrubbing, lighting and cooling systems for 72 hours.

V. Supply of Water And Food For 72 Hours Minimum

VI. **Methane, Heat, Co And Co_2 Monitors, Emergency Lighting, Warning Lights And Signage**

VII. **Toilet, First Aid Supplies, Fire Extinguishers**

VIII. **Positive Pressure, Sealings Doors And Escape Hatch**

IX. **Equipped With Skids And Fork Lift Hooks For Movement**

X. ***CACHE* house (SCSR storage)** - Given the fact that SCSRs are life saving devices, it would be unthinkable for them to be stored in a structure which would not withstand the intensity of typically measured underground fires or explosions. Inasmuch as material that will withstand the highest measured underground fire temperature and/or explosion of the highest measured intensity can be used in an affordable fashion to create storage for SCSRs, it would be recommended that the same standards concerning fire, explosion and thermal conductivity which should apply to *portable* refuge chambers, shelters or safehouses be also applied to *cache* houses for storage of SCSRs.

FOR MINE SAFEHOUSE, LLC

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Fayetteville, WV 25840

Phone: 304 574 2800, Fax: 304 574 2801
EM: conradlaw_wv@yahoo.com

ELC/am

Enclosure

Mine Safehouse

SAFE FOAM Panels

GRAFOAM™ Carbon Foam as Core Material

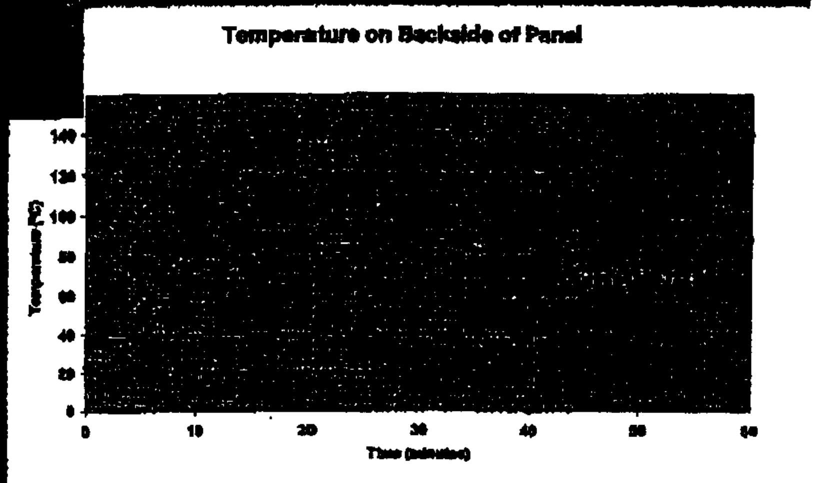
- Fire resistant
  - Outstanding fire rating
- Insulator
  - GRAFOAM™ maintains its thermal protection at elevated temperatures
  - Will not melt or ignite
- High strength and stiffness
  - No thermal creep
- Impact resistant
- Electromagnetic shielding
- Corrosion resistant

Fire Testing

- ✓ SAFETFOAM Panel *will* protect miners
- ✓ Maintains a safe environment inside
- ✓ Protects against heat transfer!

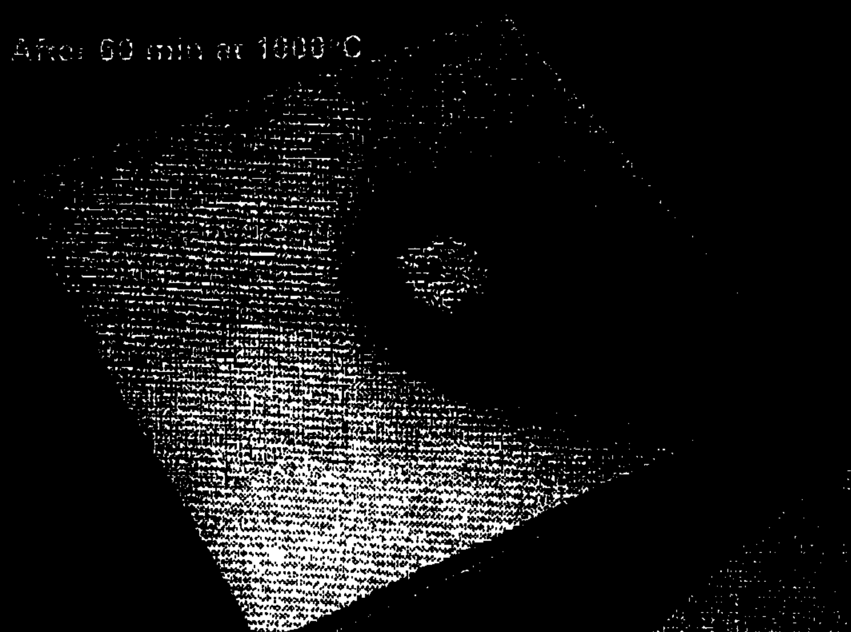
1000°C Flame

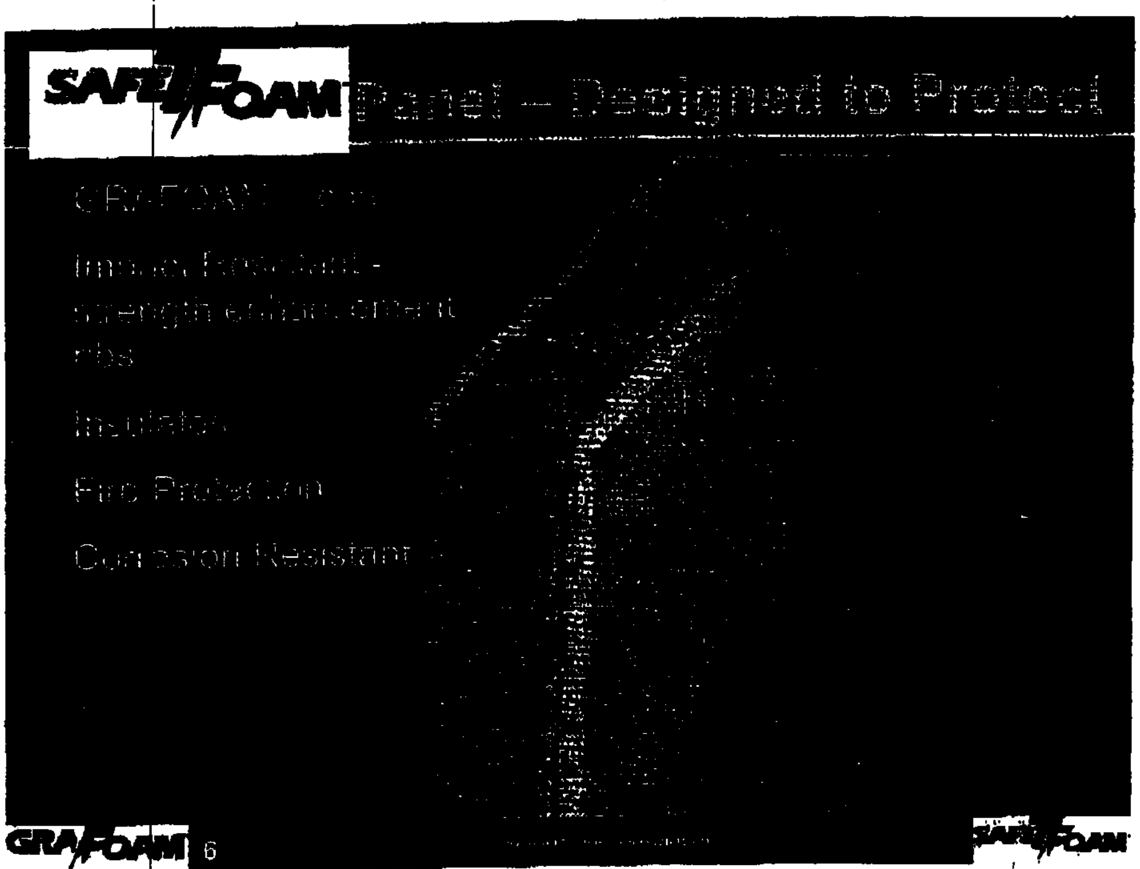
One Hour

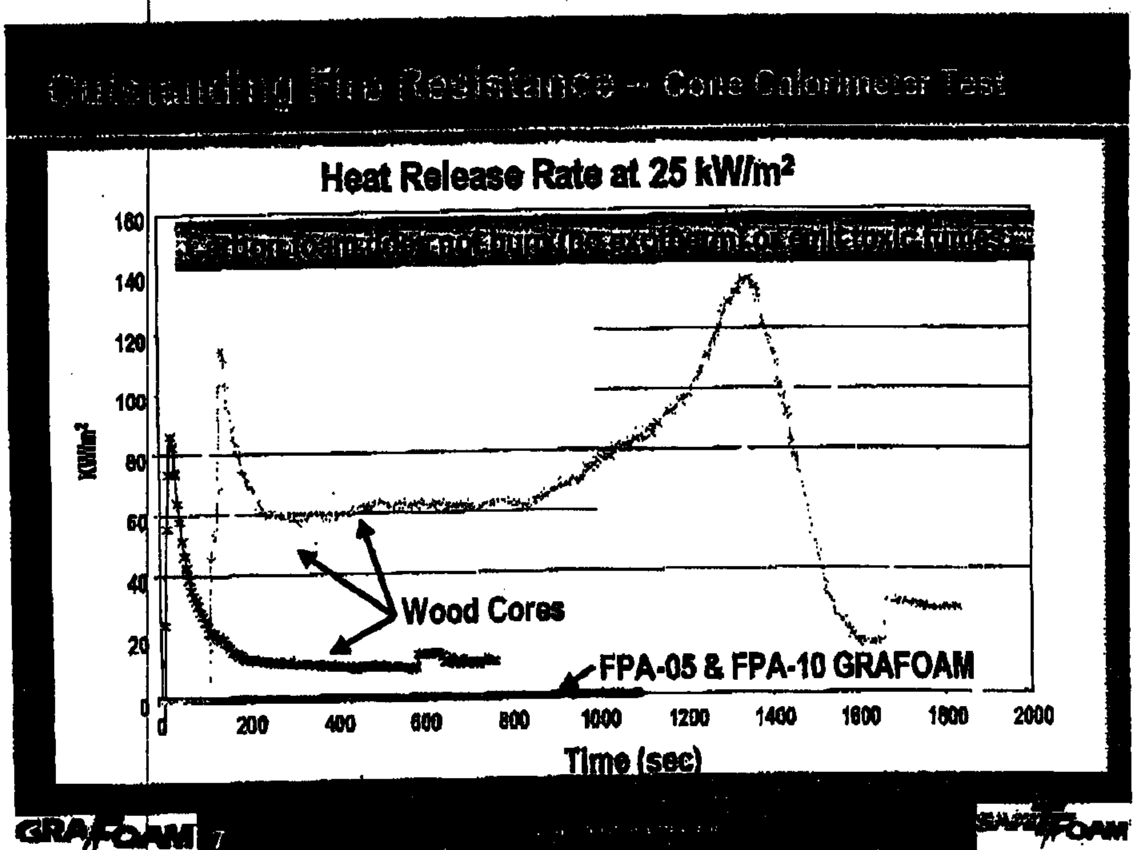


SAFETFOAM Panel will Protect Miners

After 60 min at 1000°C ...

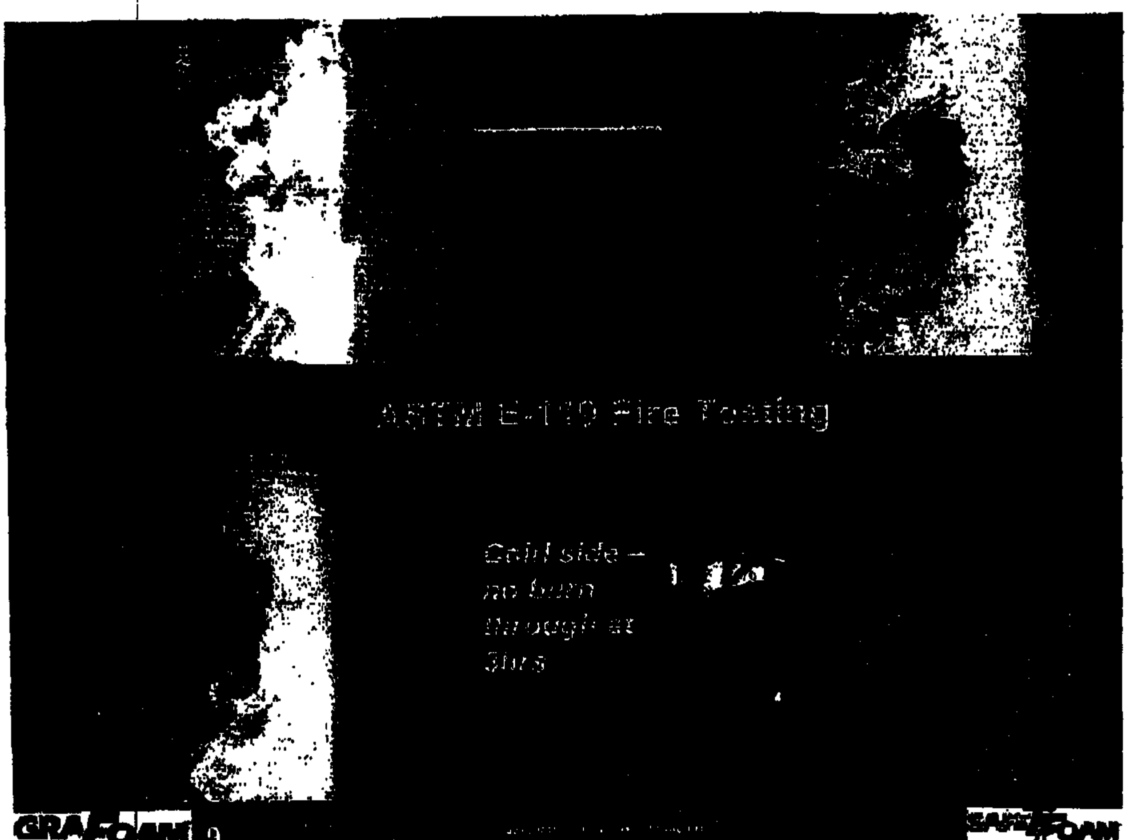


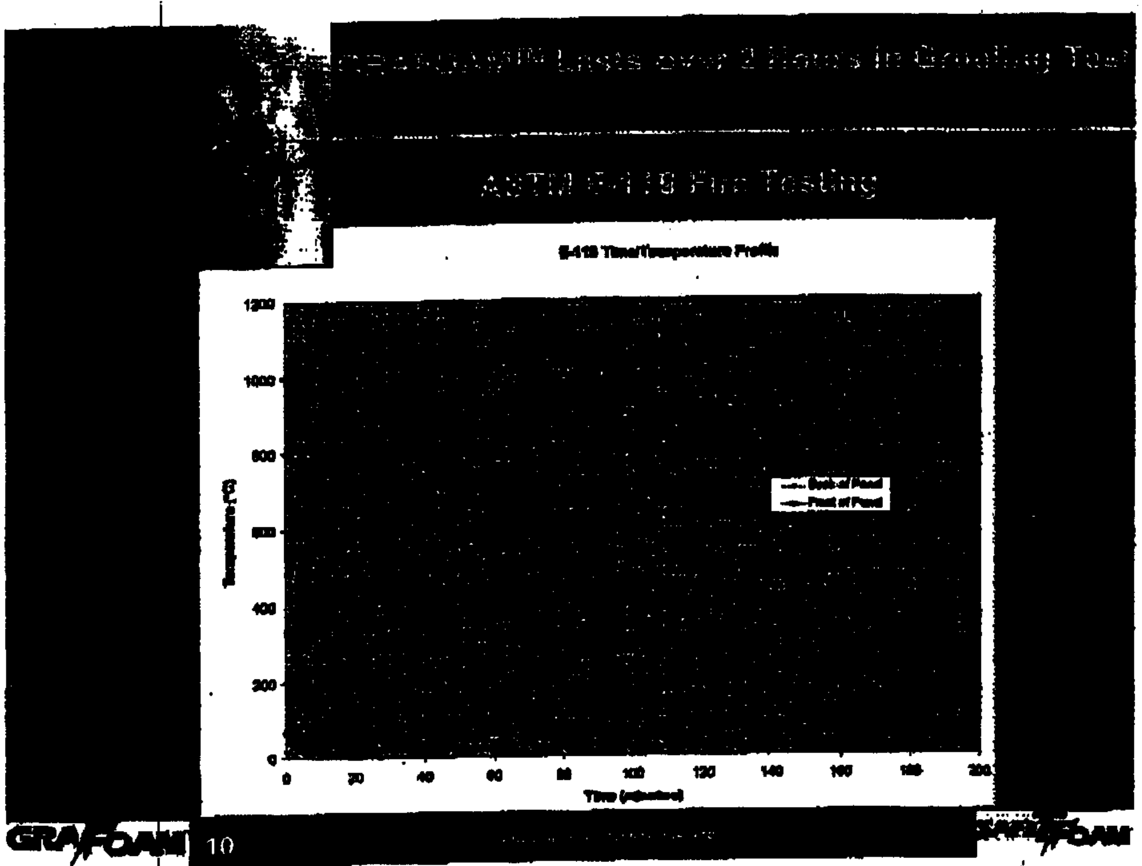

SAFEFOAM Panel – Designed to Protect
Insulation
Fire Protection
Corrosion Resistant
GRAFOAM
6
SAFEFOAM

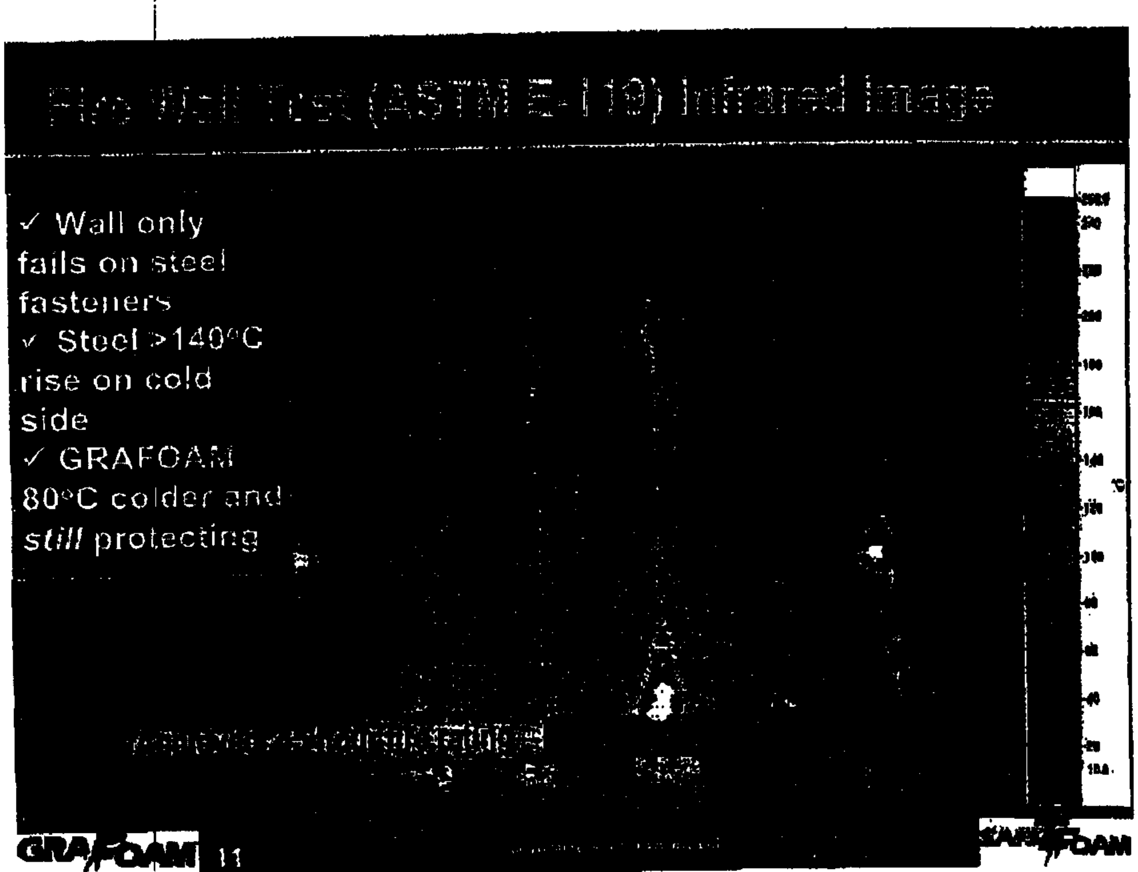

Outstanding Fire Resistance – Cone Calorimeter Test
Heat Release Rate at 25 kW/m²
KW/m²
0
20
40
60
80
100
120
140
160
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Time (sec)
Wood Cores
FPA-05 & FPA-10 GRAFOAM
GRAFOAM
7
SAFEFOAM

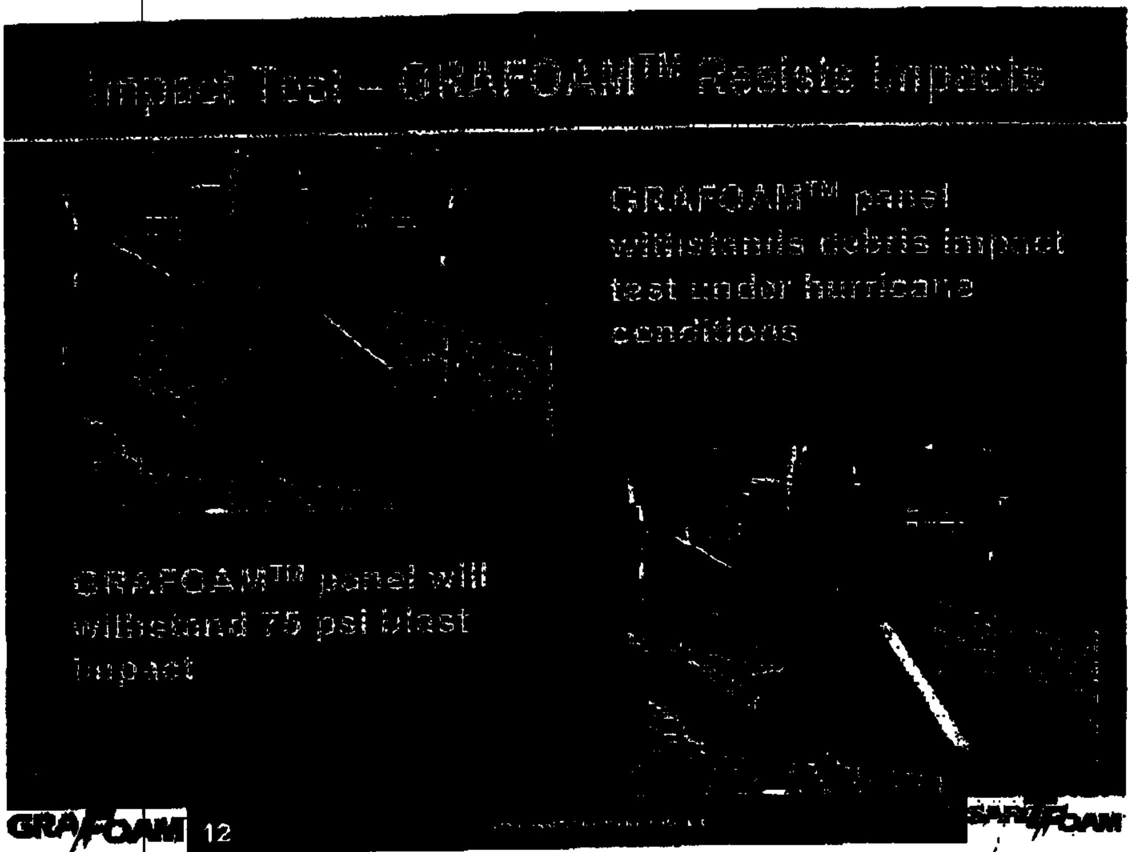
GRAFOAM™ Prevents Heat Transfer through Panel

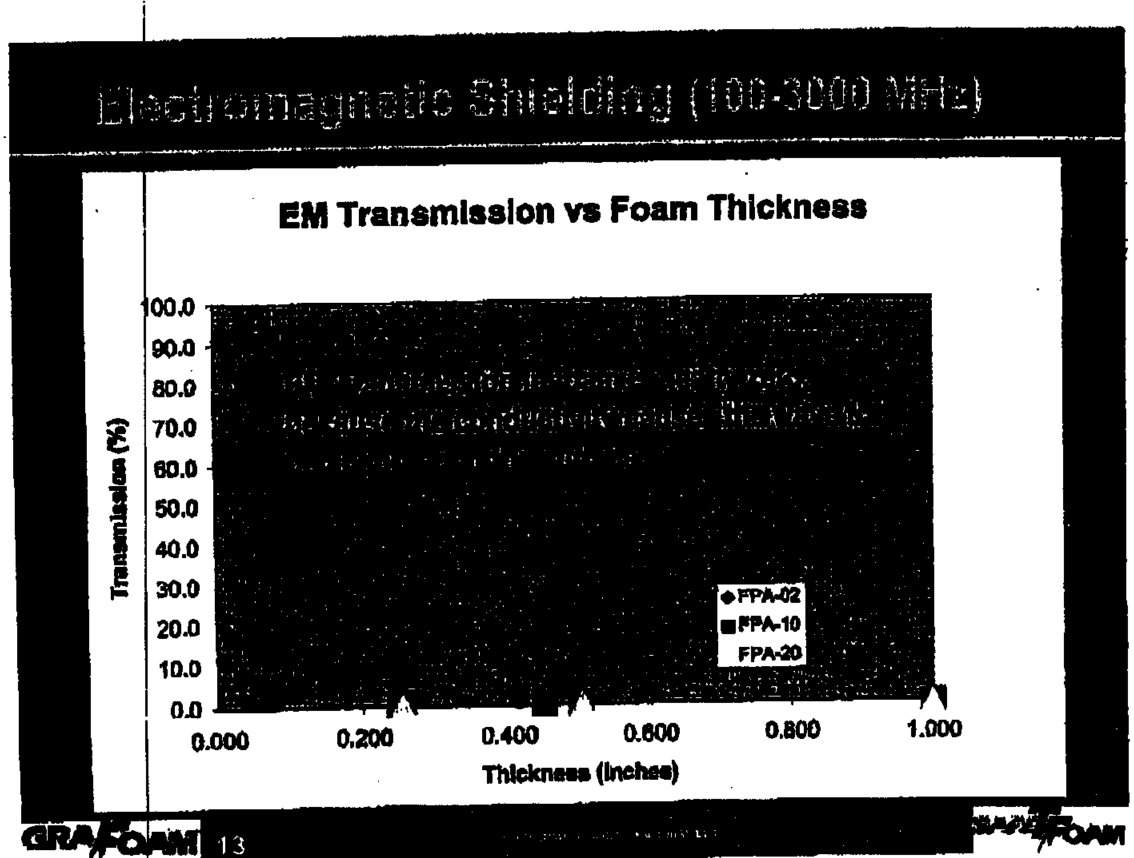
Material	Thermal Conductivity (W/mK)	Magnitude higher than GRAFOAM™
GRAFOAM™	0.1	
Glass	1.1	11 X
Steel	46	460 X
Aluminum	250	2500 X

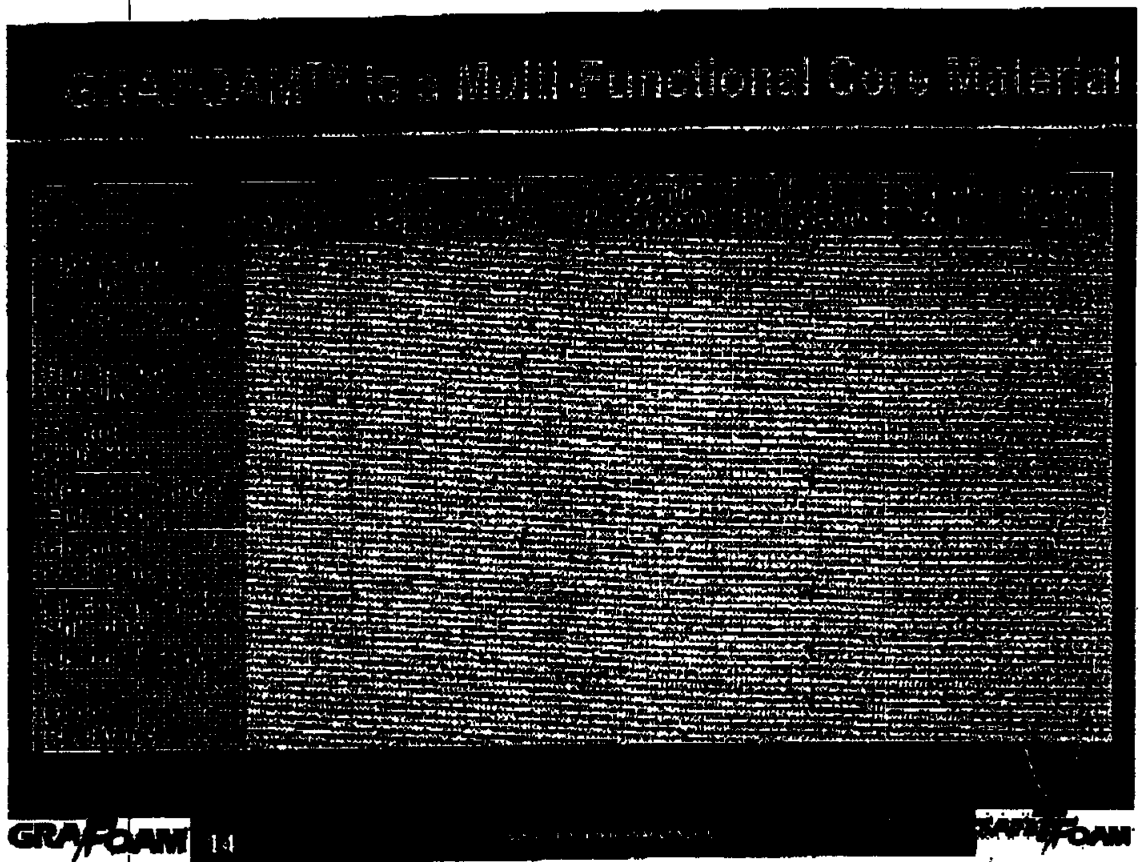


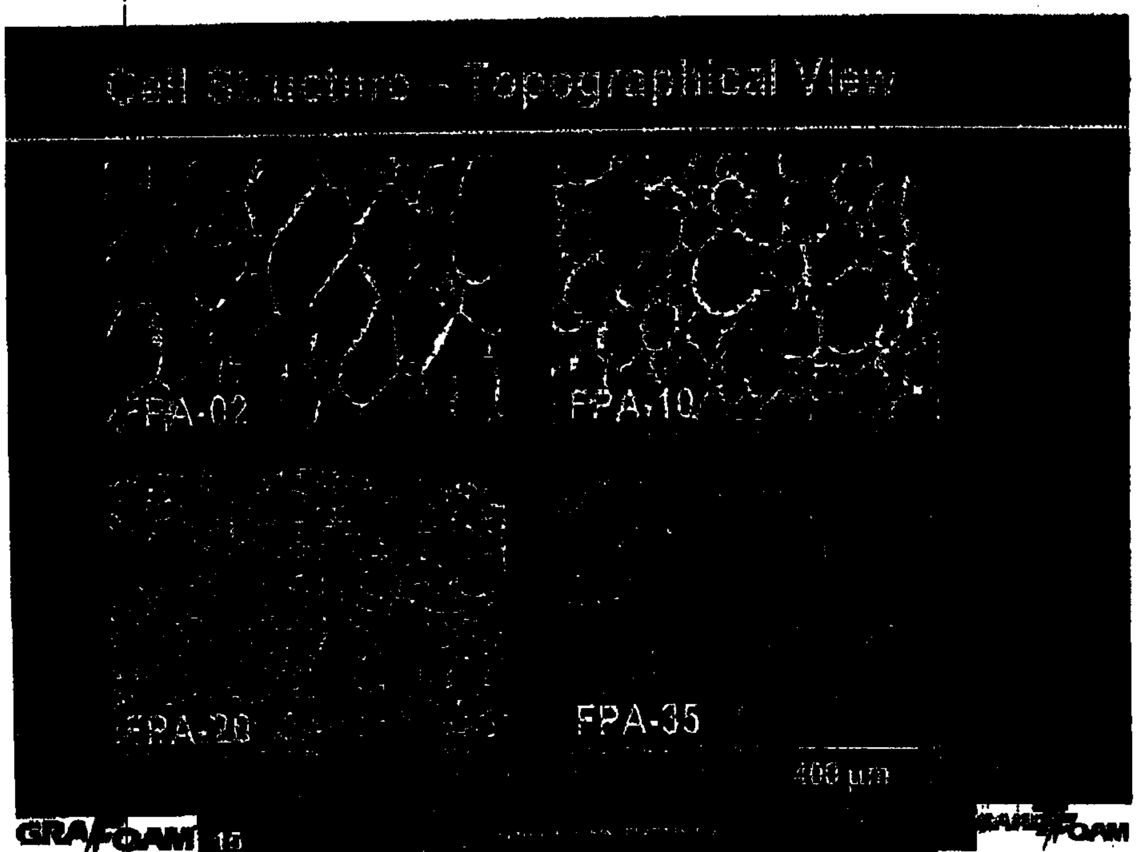

ASTM E-119 Fire Testing
1200
1000
800
600
400
200
0
0
20
40
60
80
100
120
140
160
180
200
GRAFOAM
10
GRAFOAM


Fire Wall Test (ASTM E-119) Infrared Image
✓ Wall only fails on steel fasteners
✓ Steel >140°C rise on cold side
✓ GRAFOAM 80°C colder and *still* protecting
GRAFOAM
11
GRAFOAM

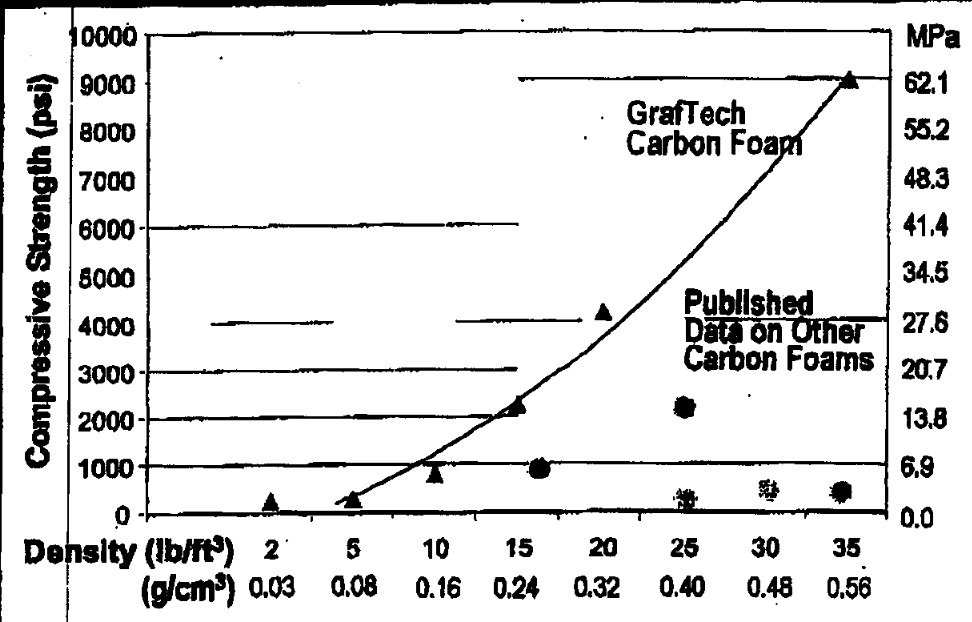

Impact Test – GRAFOAM™ Resists Impacts
GRAFOAM™ panel withstands debris impact test under hurricane conditions
GRAFOAM™ panel will withstand 75 psi blast impact
GRAFOAM
12
GRAFOAM


Electromagnetic Shielding (100-3000 MHz)
EM Transmission vs Foam Thickness
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Transmission (%)
0.000
0.200
0.400
0.600
0.800
1.000
Thickness (inches)
FPA-02
FPA-10
FPA-20
GRAFOAM
13
GRAFOAM

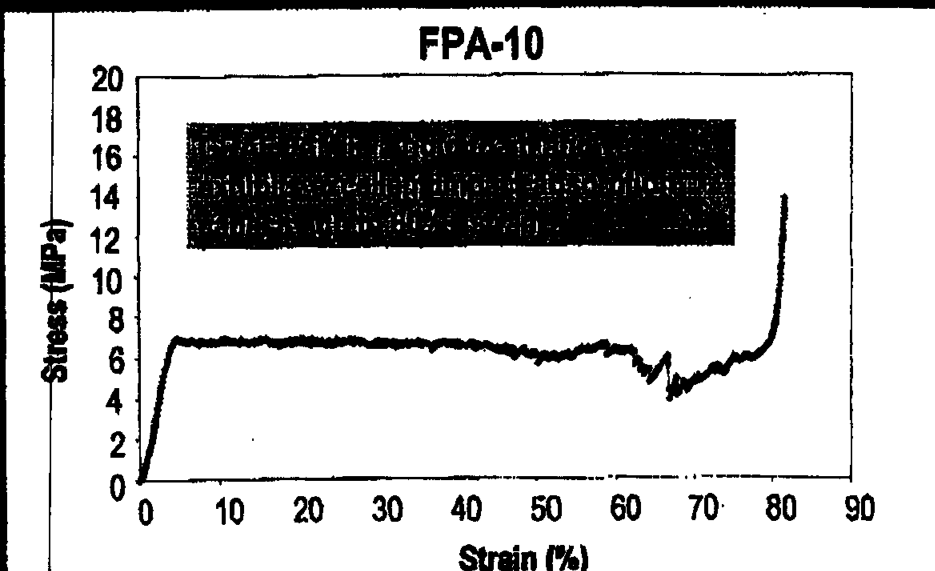

is a Multi-Functional Core Material
GRAFOAM
14

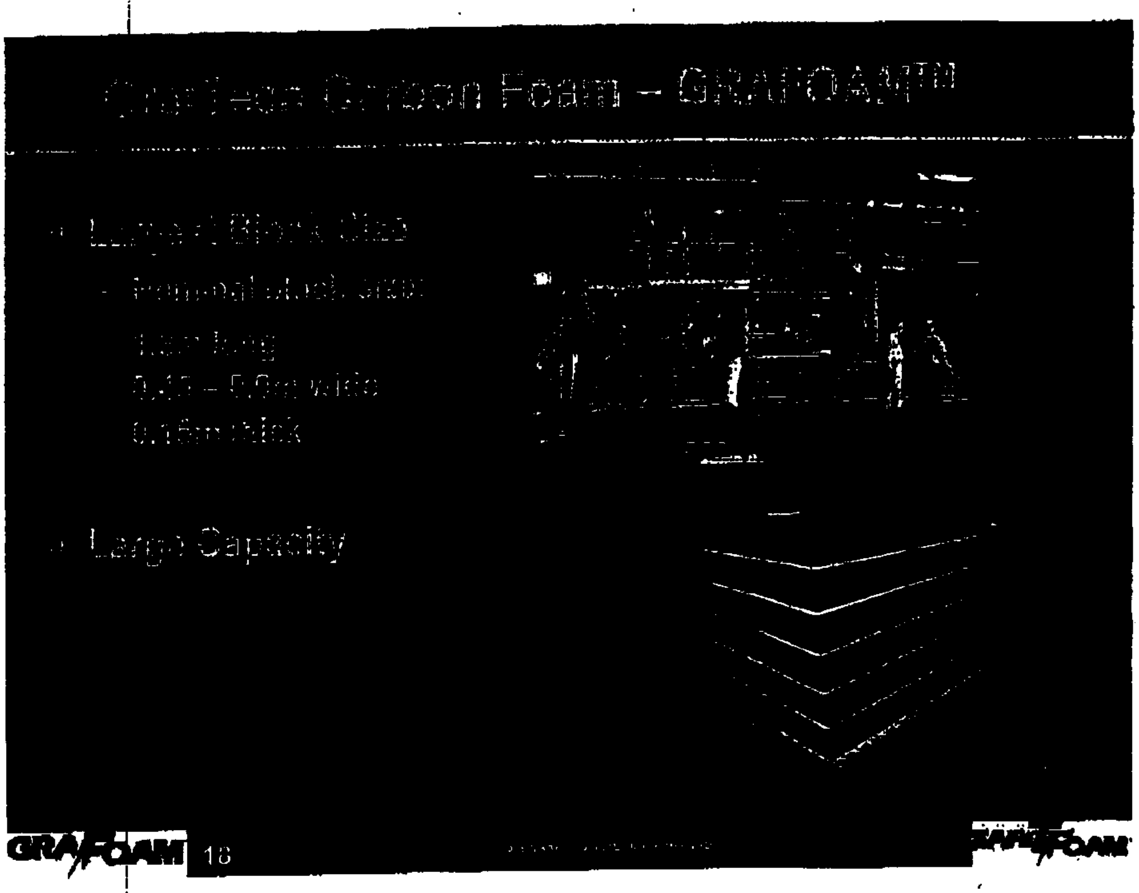

Cell Structure – Topographical View
FPA-02
FPA-10
FPA-20
FPA-35
400 µm
GRAFOAM
15

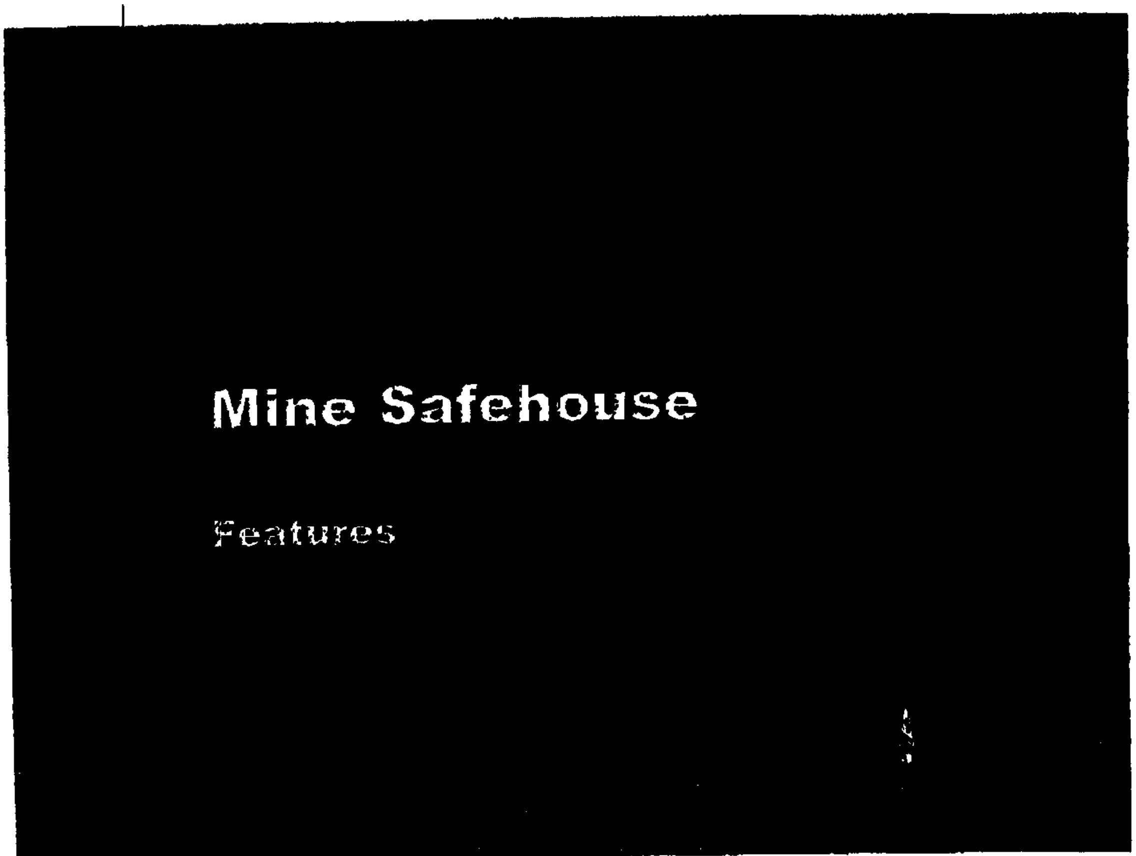
Compressive Strength



Compressive Stress-Strain Curve




Carbon Foam – GRAFOAM™
Largest Block Size
Nominal block size
0.45 – 0.6m wide
0.15m thick
Large Capacity
GRAFOAM 18
GRAFOAM


Mine Safehouse
Features

Mine Safehouse Design Parameters

Functional Requirements

- Designed to accommodate 16 miners
- Provide 72 hours of breathable air
- Provision for
  - ✓ Food/Water
  - ✓ Toilet
  - ✓ Lighting
  - ✓ Medical Kit
  - ✓ Air conditioning
- Communication equipment

GRAFOAM 20 SAFEFOAM

Mine Safehouse Design Parameters

Functional Requirements

- Air Tight to prevent ingress of toxic gases
- Waterproof
- Methane and temperature monitoring
- Additional breathable air units
- Lights signaling when to use the safehouse due to unsafe air conditions

GRAFOAM 21 SAFEFOAM

Mine Safehouse Design Parameters

Functional Requirements

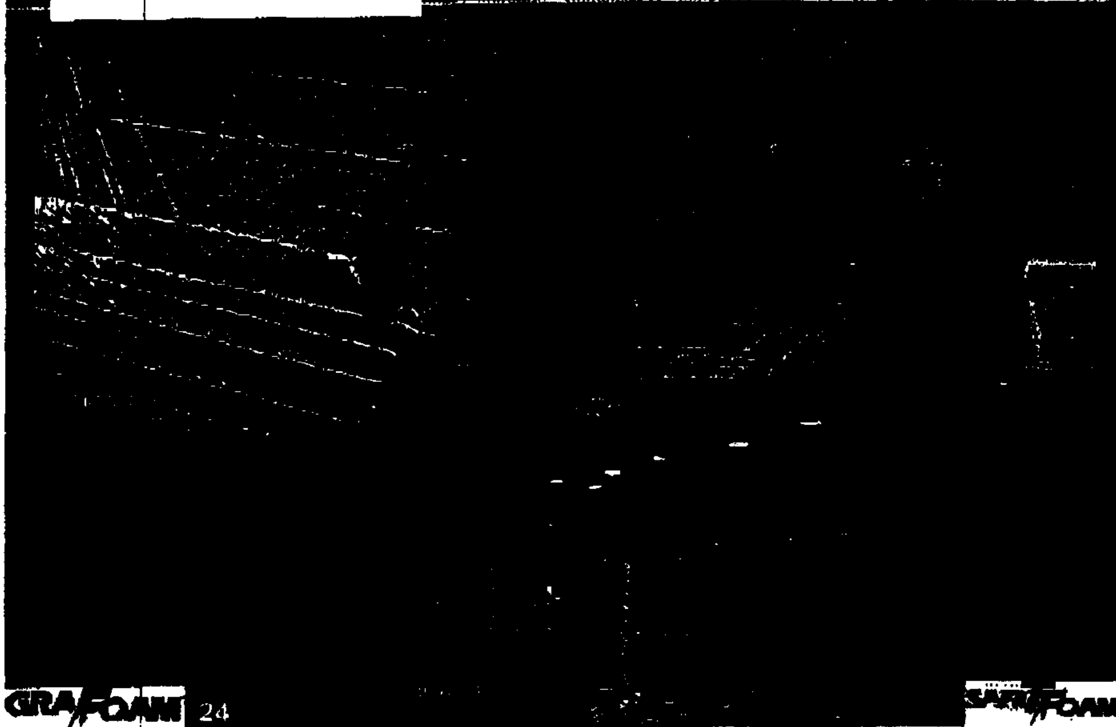
- Mobile design
- Survive repeated handling
- Puncture resistant
- Blast protection to 75 psi

GRAFOAM 22 SAFEFOAM

Mine Safehouse

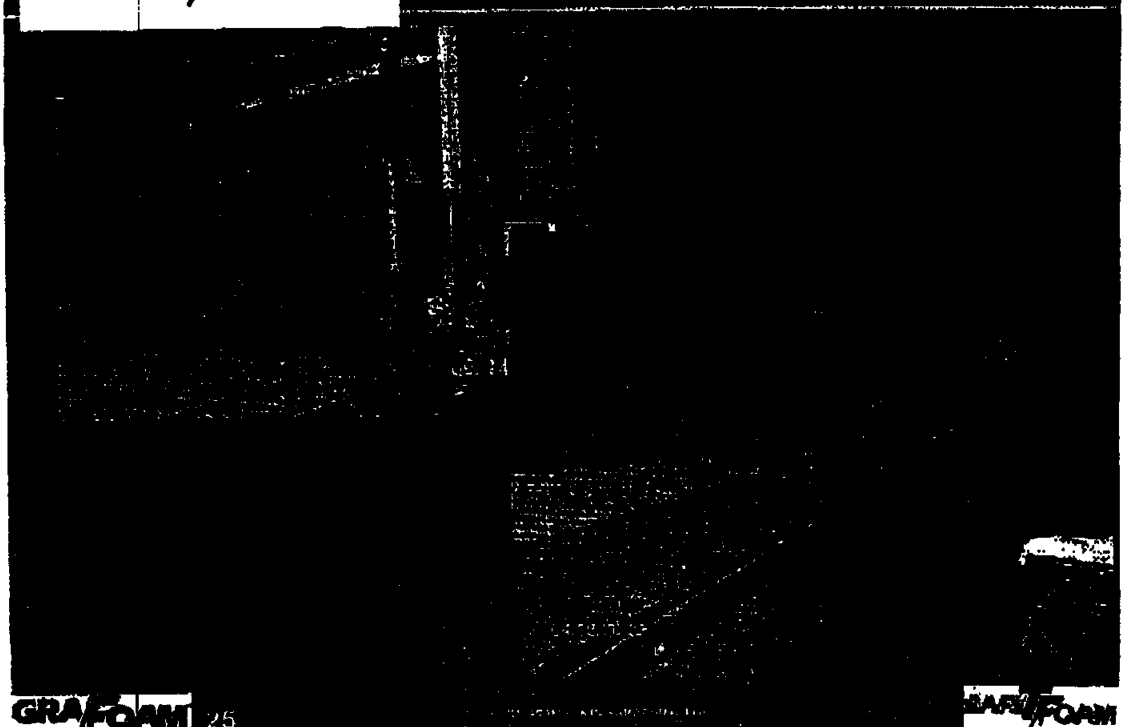
Construction

SAFE T FOAM Panel Construction

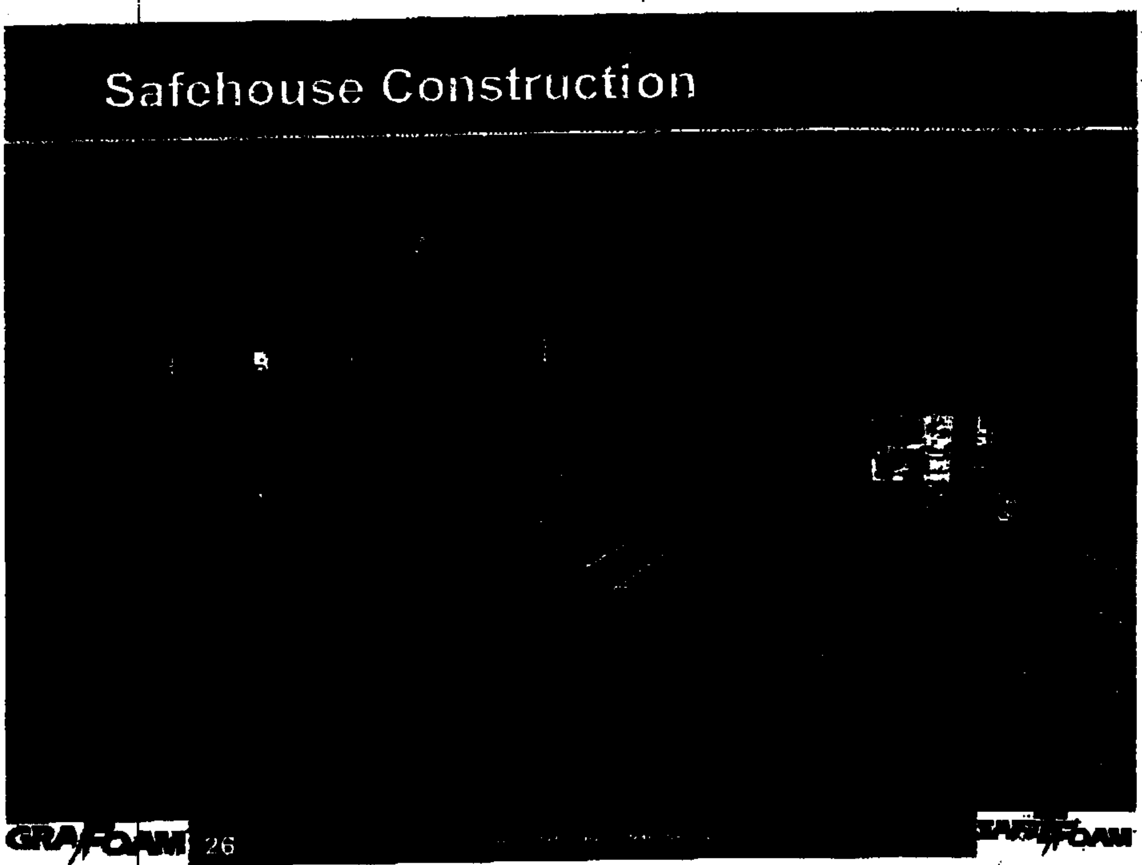


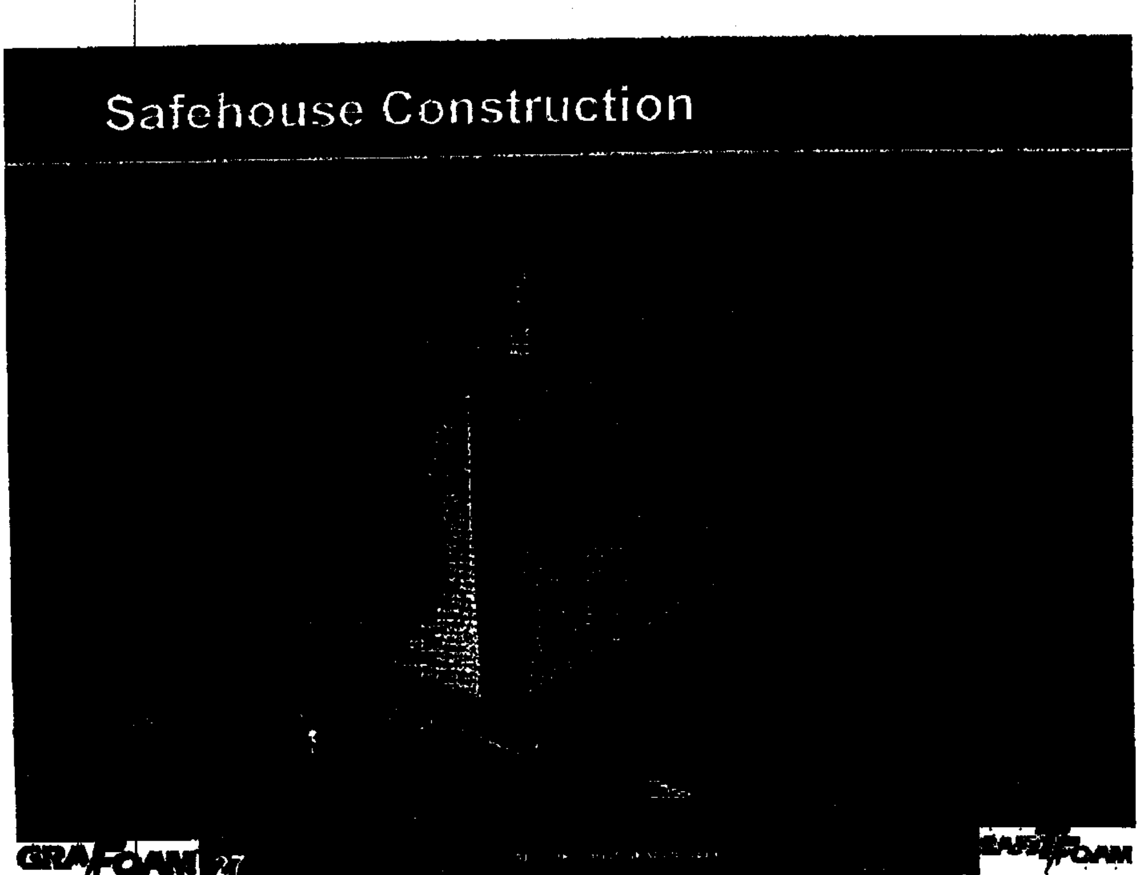
GRAFOAM 24 SAFE T FOAM

SAFE T FOAM Panel Construction



GRAFOAM 25 SAFE T FOAM


Safehouse Construction
26

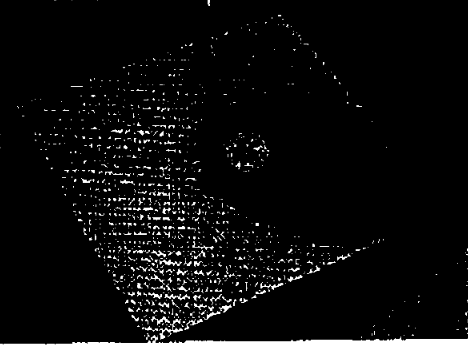

Safehouse Construction
27

Fire Retardence

Fire retardency of Mine Safe House will be accomplished through two steps

- Use of proven fire resistant structural panels and joints
- Coating the mine safe house with a tested fire retarding intumescent paint

After 60 min at 1000°C



Why CFC for Mine Safehouse?

- Mine safehouse built with composites structural panels will have the following advantages
  - Fire retardant without significant cost (i.e., no need for high temperature alloys)
  - Light weight for easy transportation
  - Durable for long term use in underground mine environment

Constructed Facilities Center is uniquely positioned to design and develop a composite safe house by leveraging its extensive R&D experience in structural composites.

Mine Safehouse

Partners

Fiber-Tech Industries, Inc

Another Celstar Company

FTI Fiber-Tech Industries, Inc

Another Celstar Company

Serving the Construction, Marine, & Transportation Markets with Structural Fiberglass Reinforced Panels!

Up to 10' x 58' Seamless Panels

FTI Fiber-Tech Industries, Inc

Another Celstar Company

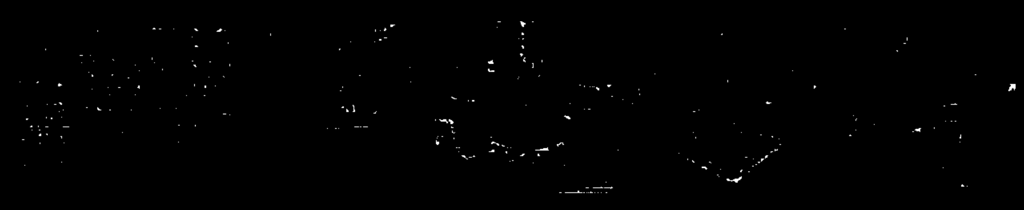
Three Manufacturing Locations in the U.S.

Washington Michigan Ohio

www.fiber tech.net

Carbon Foam

GRAFTECH
GrafTech International Ltd.



Tradition & Excellence

- 1886: Founded as the National Carbon Company

- GrafTech International Ltd.
  - $848 million revenue
  - 3,900 employees
  - Industry leading global supplier
  - ISO & QS certified

GrafTech International LTD.
Extensive Manufacturing Network

GTI Vision
We enable customer leadership, in new and existing markets, better and faster than our competition, through the creation, innovation and manufacture of carbon and graphite material science based solutions

GRAFOAM 36 GRAFOAM

GrafTech Builds on Core Strengths:

100 years expertise in Carbon/Graphite Science

- Fuel Cells – Ballard partnership
- Electronic Thermal Management – displace Cu & Al in computers, TV screens, cell phones
- Electrodes – introduced revolutionary product in 2004
- GRAFOAM™ Carbon foam - aerospace, transportation, marine



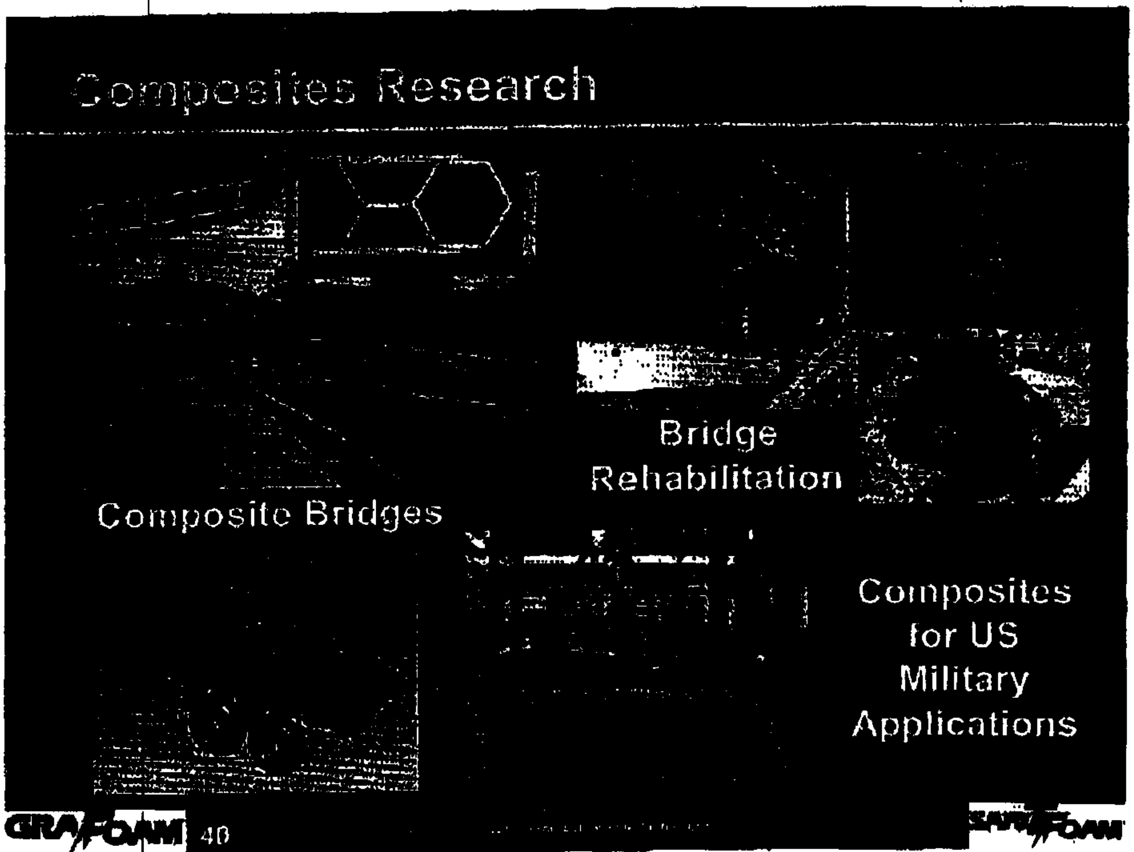
GRAFOAM

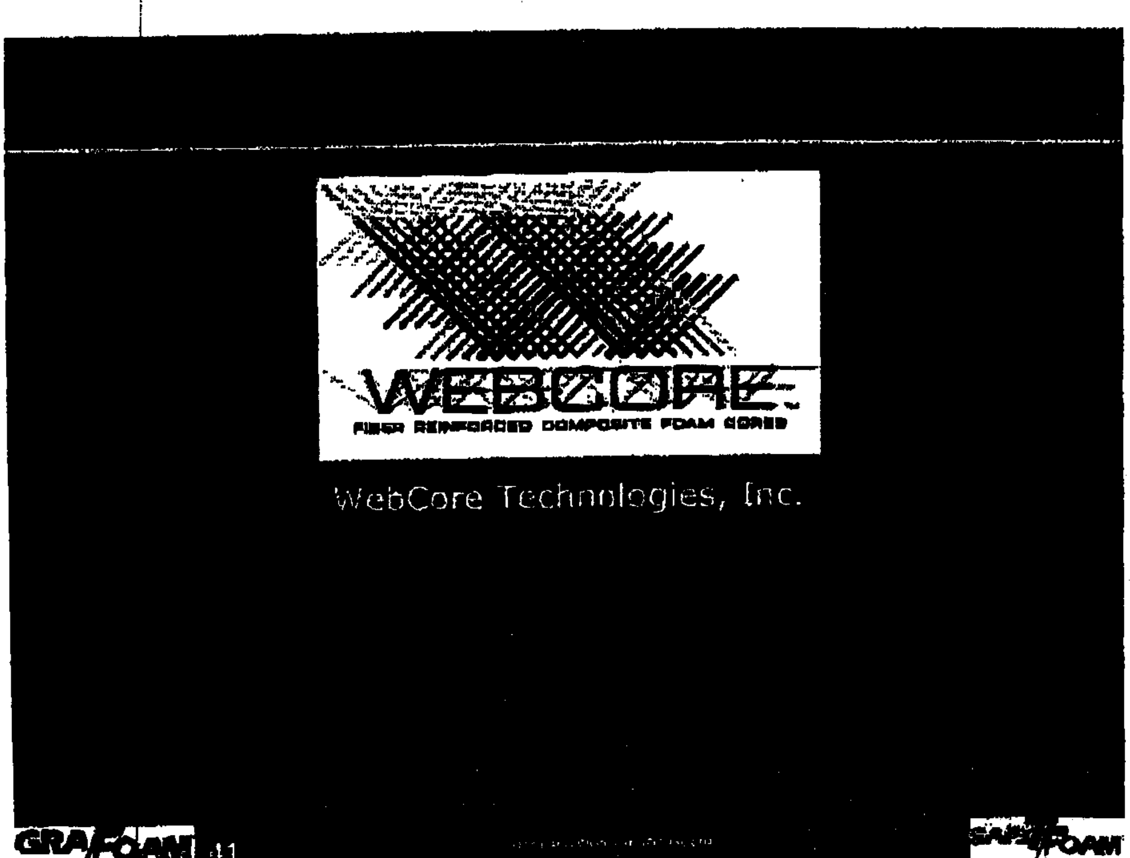
WestVirginiaUniversity.
Where Greatness is Learned

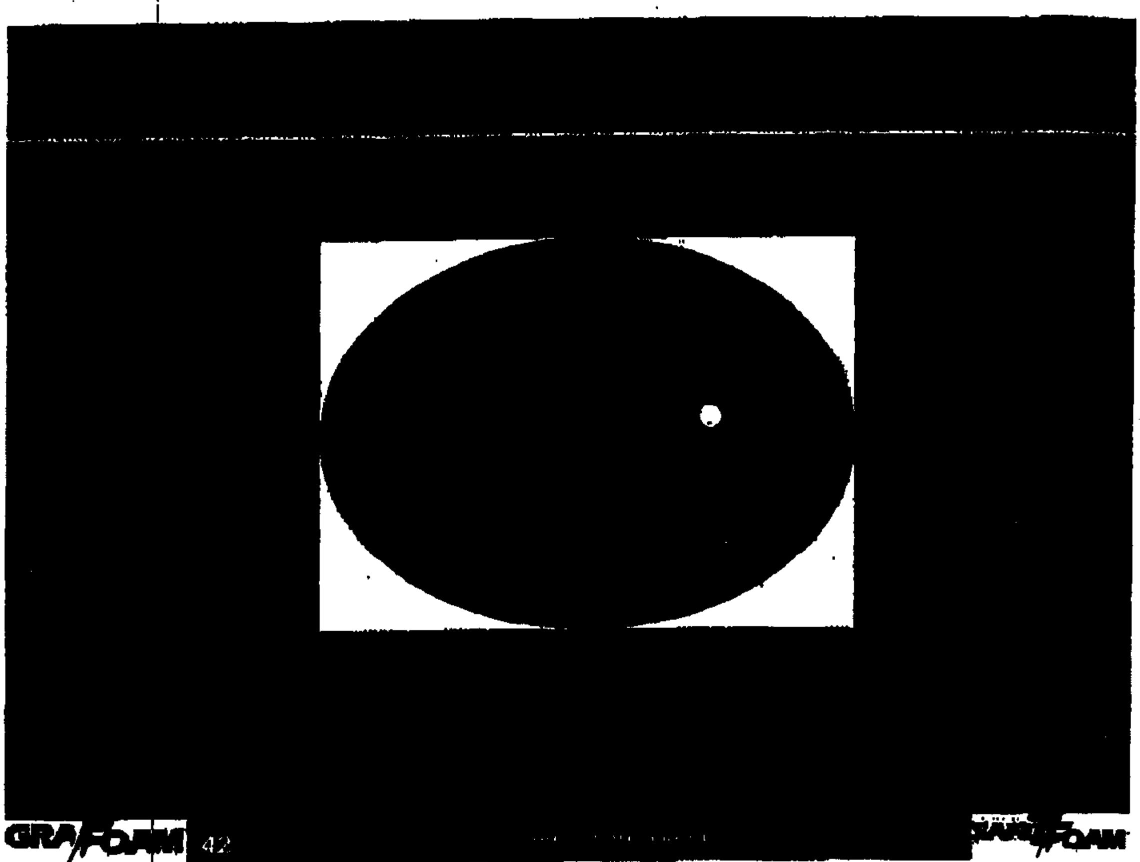
Constructed Facilities Center – West Virginia University (CFC-WVU)

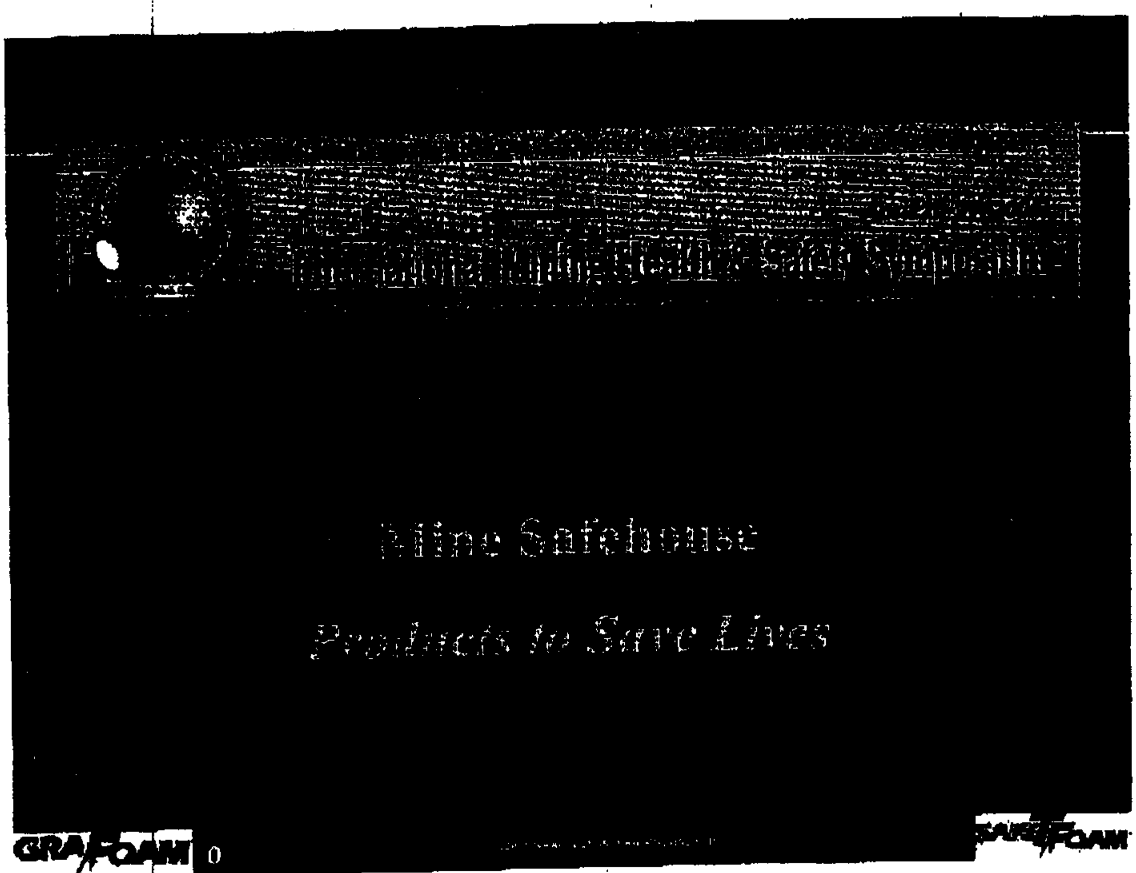
Some of the R&D at CFC – WVU

- Development of structural fiber reinforced composite components (e.g., bridge decks)
- Rehabilitation of existing (concrete & timber) structures using glass and carbon composites to improve their service life and durability
- Research into advanced composite technologies
  1) nano composites
  2) fire retardant resins
  3) 3D stitched fabrics


Composites Research
Bridge Rehabilitation
Composite Bridges
Composites for US Military Applications
40


WEBCORE
FIBER REINFORCED COMPOSITE FOAM CORES
WebCore Technologies, Inc.
41





Safehouses, Saferooms, Cache Houses

-products to save lives

Built in cooperation with the following companies:

Fiber-Tech Industries, Inc.

WebCore Technologies, Inc.

For more information call Bret Chandler: (304) 755-8811 or email: blchandler@clarktruck.com

DOCUMENT 13

Major Hazard Management in Australian Coal Mining

Jim Joy
Professor and Director
Minerals Industry Safety and Health Centre
Sustainable Minerals Institute
The University of Queensland, Australia

Minerals Industry Safety & Health Centre (MISHC)

- established in 1998
- an initiative of Industry, Government and UQ
- recognition that engineering education has a critical role in improving S & H risk

MISHC Postgrad courses

- Risk Management (G3)
- Human Factors
- Risk Analysis
- Sociology of Disasters
- Incident Investigation & Analysis
- Mining OH&S
- Special Projects I & II

4 or all of

UQ Graduate Certificate or Diploma in Risk Mgmt.

Masters/ PhD

Since 1990

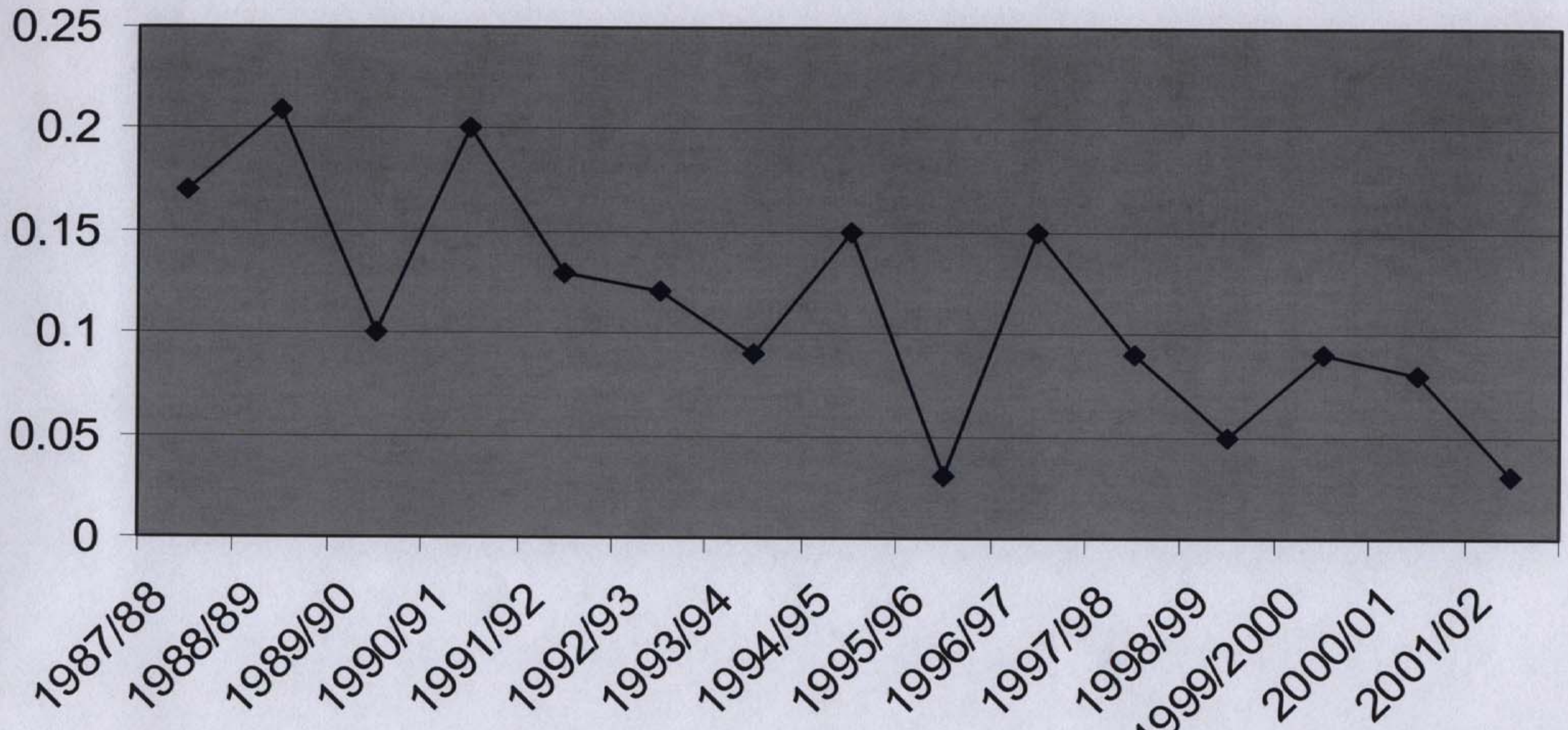
Moura explosion (11)

Gretley Inrush (4)

Northparkes airblast (4)

Bronzewing fill inrush (3)

Australian Mining Industry Fatality Rate per Million Man Hours Exposure



Mining Regulatory Approach

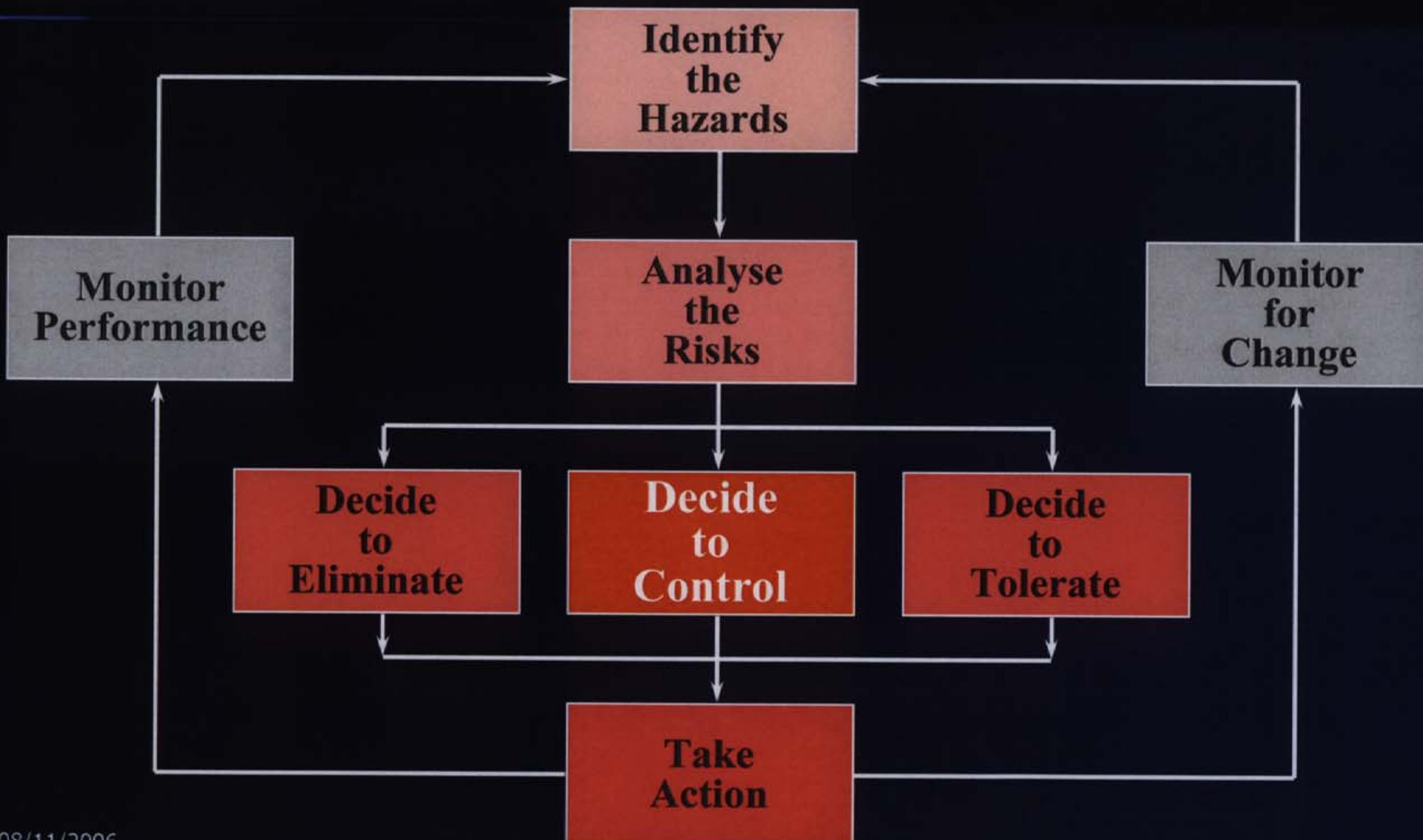
MISHC

Prescriptive about Actions	Prescriptive about Process	Enabling
Govt. tells how, Industry complies, Govt polices	**Govt sets approach, Industry decides how using approach, Govt coaches**	**Industry decides how, Govt monitors results**

Regulatory Manifestations

1. General principles of RA & RM
2. Major or Principal Management Plans
3. RM competency requirements
4. Use of RA as "approval" methodology

Basic Risk Management System



Control Framework

Why use Major Hazard Management Planning?

- ✓ to manage potential multiple fatality events
- ✓ to do it more effectively and efficiently

- ✓ to meet regulatory requirements
- ✓ to improve business success

Major Hazards

Post Moura

- spon comb
- UG fire
- ventilation / gas
- ground control
- & others

New legislation additions

- Fixed & mobile mechanical
- Electricity
- Windblast

The MHM Process

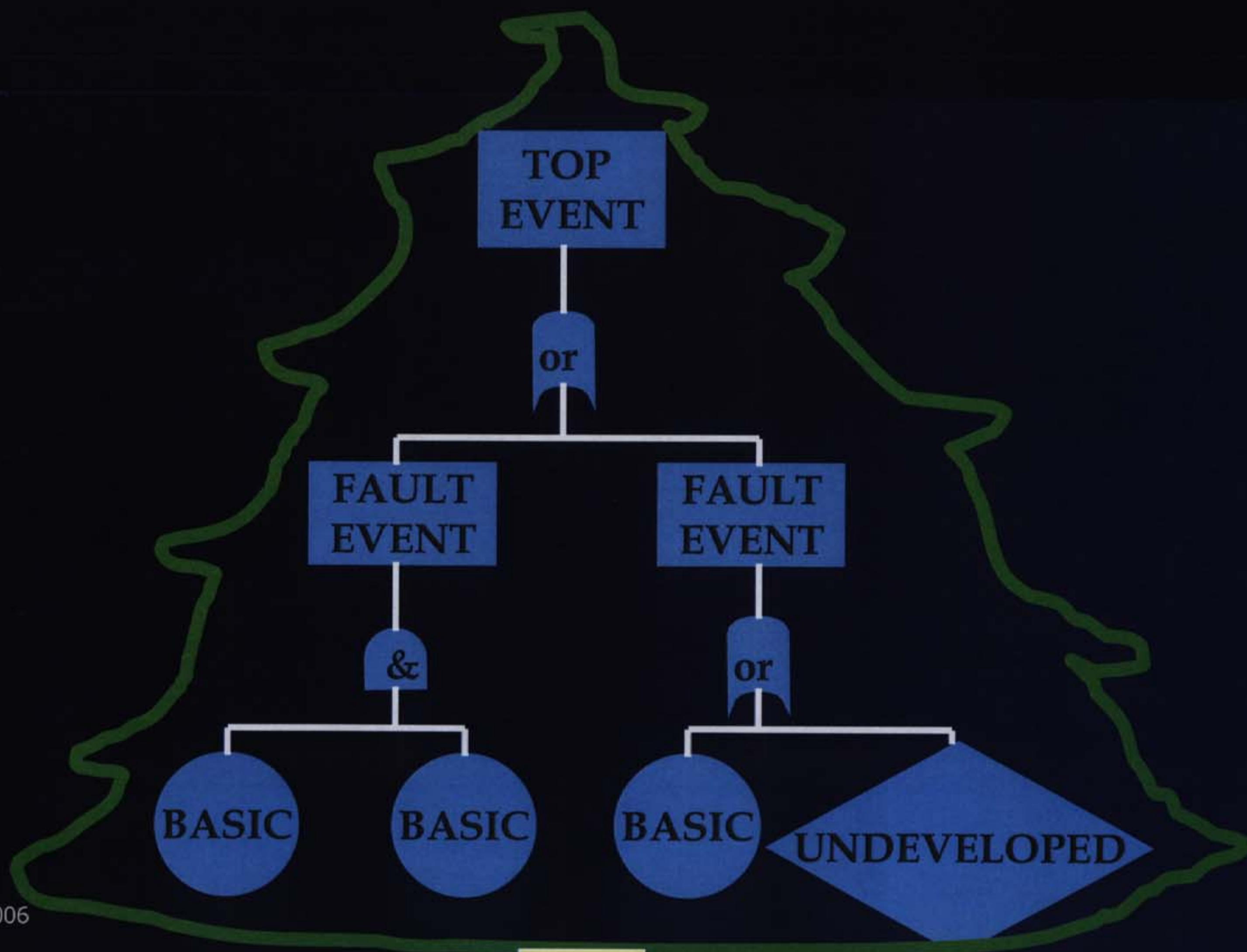
1. Identify the Major Hazards
2. Review the Hazard (location, risk, controls)
3. Determine important existing & new controls
4. Document (Action Plan, Standards, Accountabilities, etc.)
5. Implement
6. Monitor / Audit
7. Manage change

Reviewing the Major Hazard

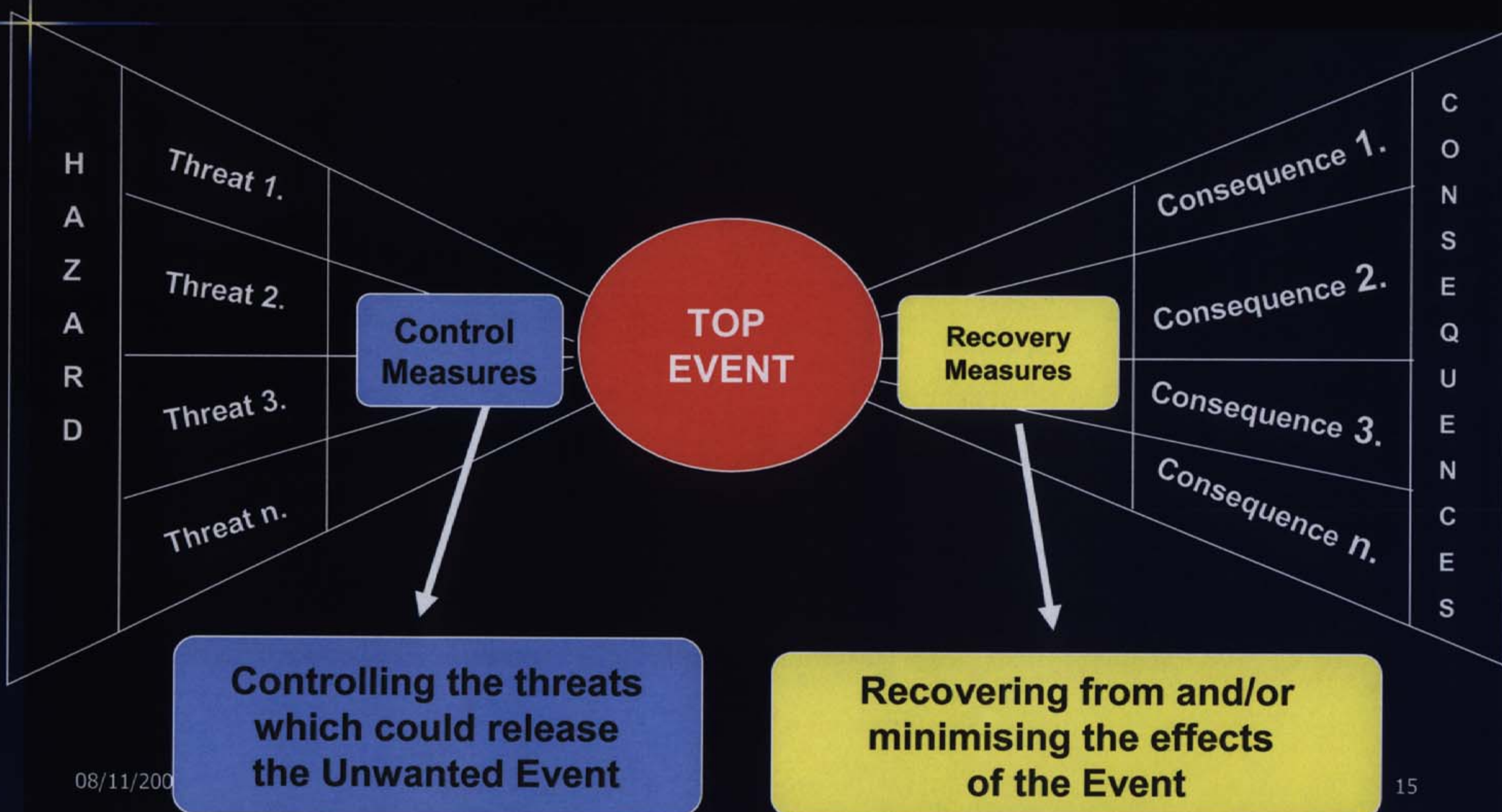
Risk Assessment

- Identification of the major hazards (nature, magnitude, locations)
- Detailed analysis of the major hazards

Fault Tree Analysis



BOW TIE ANALYSIS



Control Framework

Minerals Industry Cooperation Initiative (2003-06)

MISHC

MICI

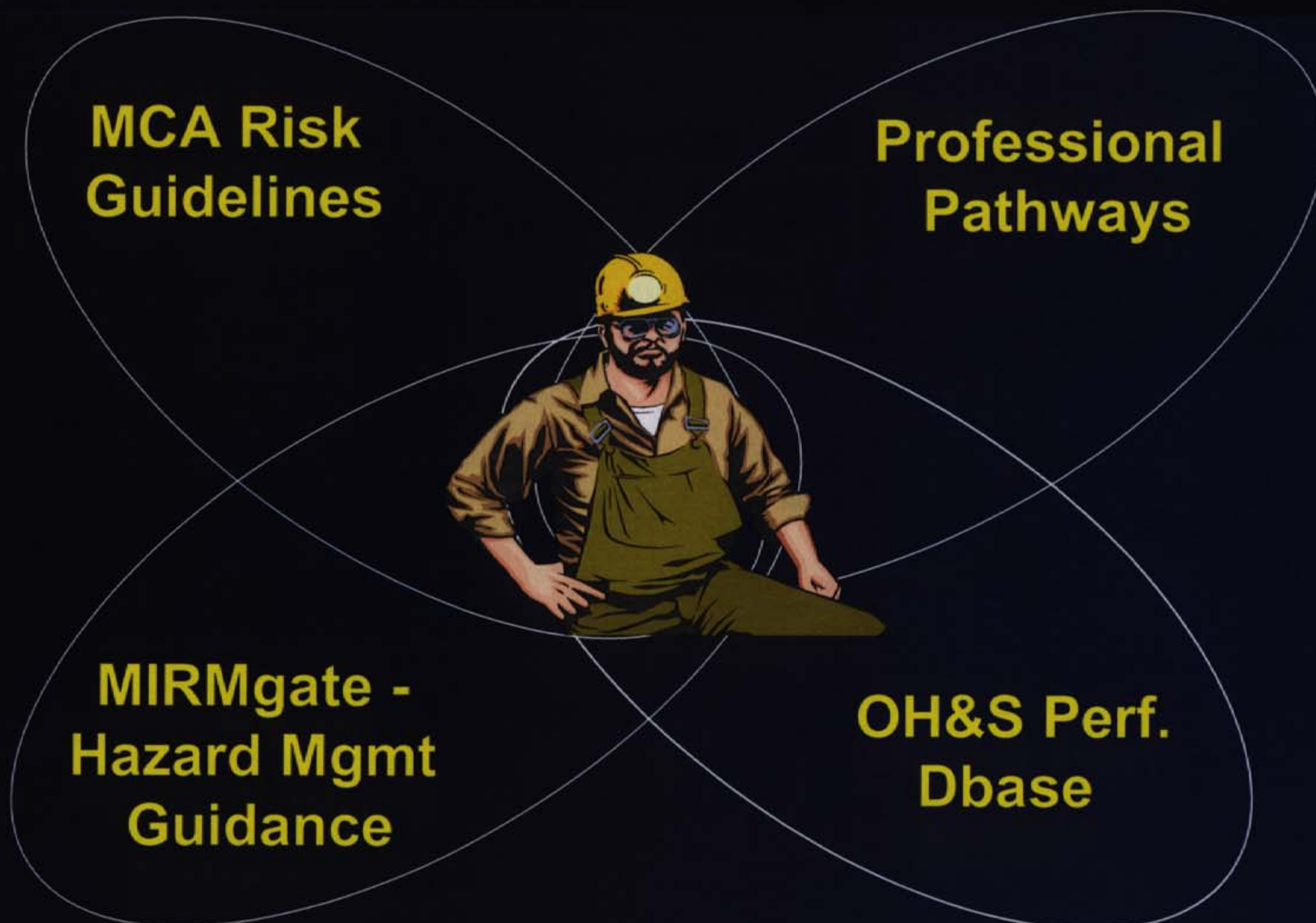
Goal:

To improve industry RM, as well as demonstrate industry cooperation

08/11/2006

MINERALS COUNCIL OF AUSTRALIA

MICI - 2003-06 "Hard" Projects



MICI - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://www.mishc.uq.edu.au/miciweb/index.asp

MICI

MISHC | Risk Assessment Guideline | Risk Management Guideline
MIRMgate | Professional Pathways | Health Tracking Project

MICI Links
- Introduction
- Documents
- News

General Links
- Personnel

- MISHC
- MIRMgate
- Risk Management Guideline
- Risk Assessment Guideline
- Professional Pathways
- Health Tracking Project

The Minerals Industry Co-operation Initiative

Welcome to the Minerals Industry Co-Operation Initative (MICI). MICI was established in 2003 as a combined effort from minerals industry representatives to reduce accident rates within mining. MICI is currently supported by the Minerals Council of Australia and is underpinned by a number of projects and developed industry resources.

You may access the different projects through the tabs in the centre of this page or through the title bar. General information about MICI is available through this site.

Note: THIS PAGE AND ALL MICI PROJECT PAGES ARE CURRENTLY UNDER CONSTRUCTION

Detailed Introduction...

 | Design After Aurum3

www.mishc.uq.edu.au

Done | Local intranet

Start | Junk E-mail - Microsoft... | 2 Internet Explorer | MIRMgate | Microsoft PowerPoint -... | 2:11 PM

Risk Management Guideline - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://www.mishc.uq.edu.au/rmg/index.asp

National Minerals Industry
Risk Management Guidlines

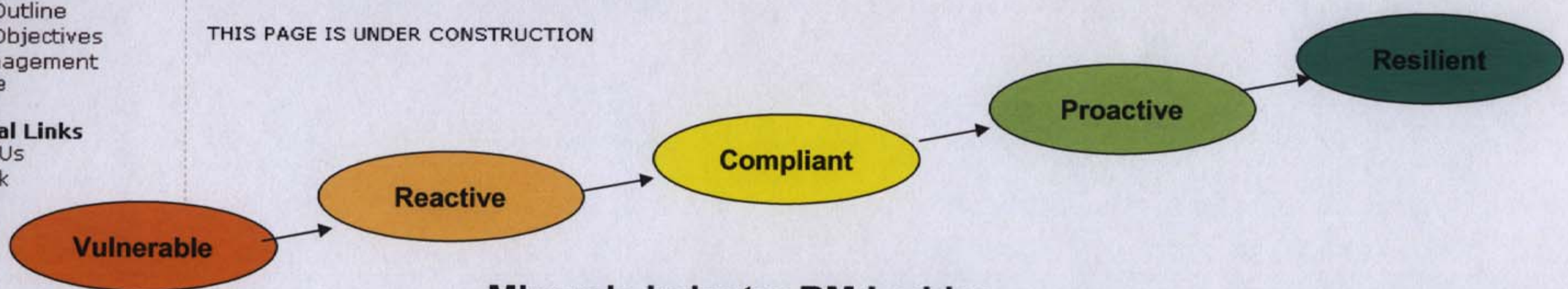
MICI Home | Risk Assessment Guidelines | MISHC
MIRMgate | Professional Pathways | Health Tracking Project

RMG Links
Project Outline
Project Objectives
Risk Management Guideline

General Links
Contact Us
Feedback

Welcome to the Risk Management Guideline

THIS PAGE IS UNDER CONSTRUCTION



Minerals Industry RM Ladder

NATIONAL MINERALS INDUSTRY SAFETY AND HEALTH RISK MANAGEMENT GUIDELINE 2006

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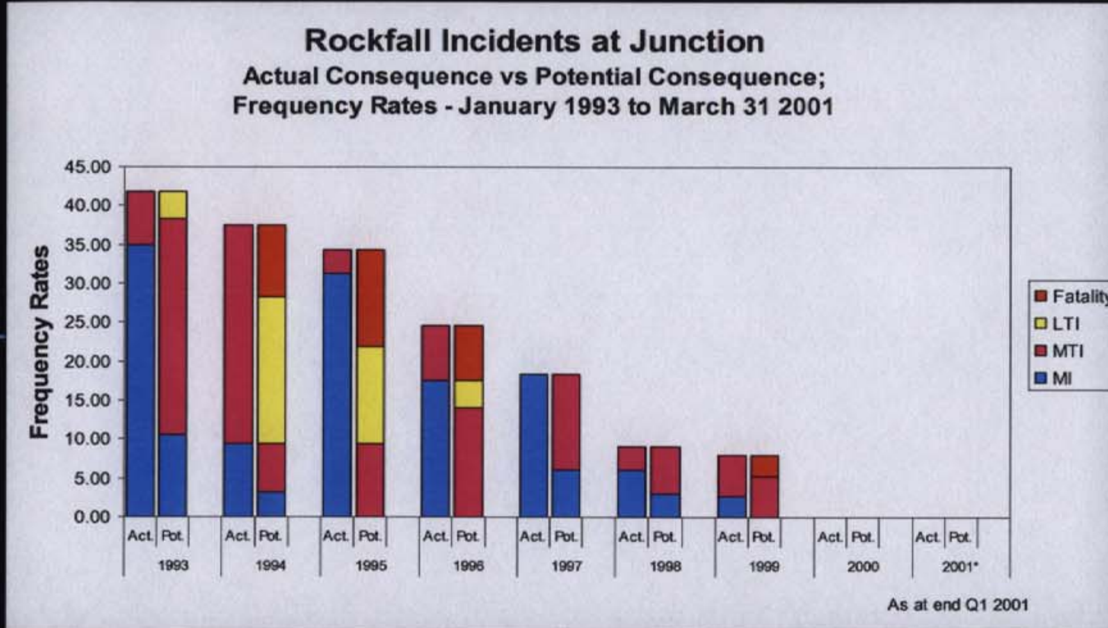

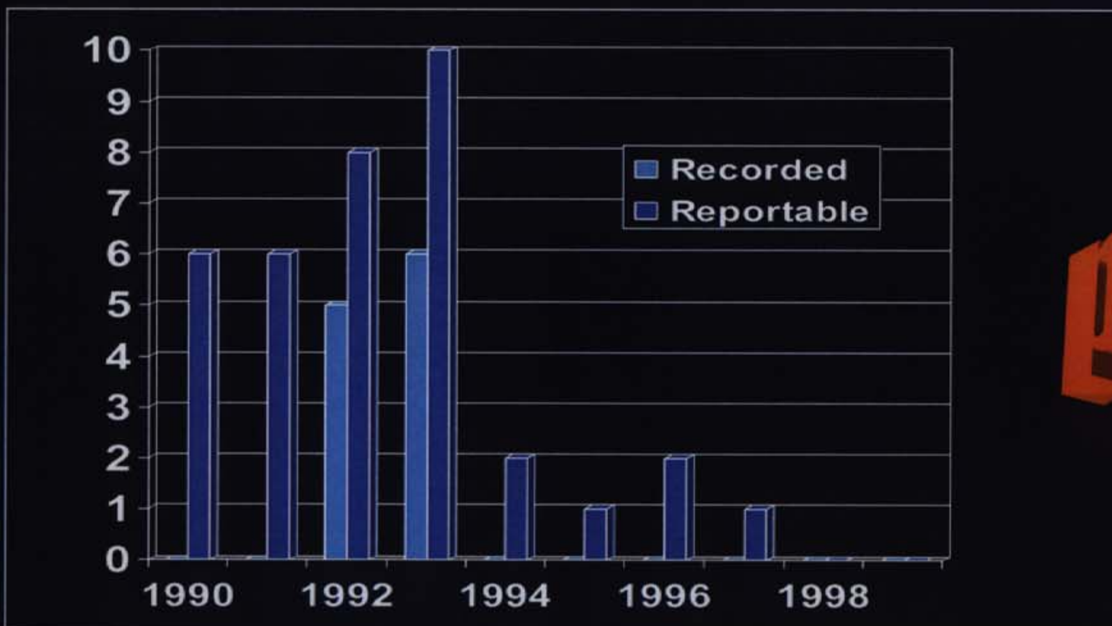

We are making progress !!

DOCUMENT 14

TRANSCRIPT OF PROCEEDINGS

In the Matter of:)
)
MINE PLANNING AND EMERGENCY)
SHELTERS WORKSHOP)

Pages: 1 through 290

Place: Washington, DC

Date: April 18, 2006

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Washington, D.C. 20005-4018
(202) 628-4888
hrc@concentric.net

U.S. DEPARTMENT OF LABOR

In the Matter of:)
)
MINE PLANNING AND EMERGENCY)
SHELTERS WORKSHOP)

Tuesday,
April 18, 2006

National Academy of Sciences
Auditorium
2101 Constitution Avenue, N.W.
Washington, D.C.

The meeting in the above-entitled matter was convened, pursuant to Notice, at 8:00 a.m.

BEFORE: JEFFERY KRAVITZ and
GERALD FINFINGER

PARTICIPANTS:

STEPHEN ALEWINE, Electrician/Miners Rep
Lafarge North America

RICHARD ALLWES, MSHA

LISA ARMSTRONG, Director of Marketing, Honeywell

KENT ARMSTRONG, Division Sales Manager-Canada
Draeger Safety

DAVID BAINES, Molecular Products, Ltd.
Mill End, United Kingdom

ALAN BECKER, PCCI, Inc.

ALLAN BECKMANN, Intern,
Senator Edward Kennedy Office

TERRY BENTLEY, Chief, Division of Safety, MSHA

RANDY BERRY, Senior Staff, Foster-Miller, Inc.

PARTICIPANTS (continued):

RICHARD BOSSERMAN, Cambria County Association for the Blind

DALE BOWERS, Consultant, Mureco, Ltd.

TOM BRADY, NIOSH Spokane Research Laboratory

ADAM BROWN, Project Manager/Safety Director, Transco

MIKE BRNICH, NIOSH - Pittsburgh Research Lab

JURGEN BRUNE, NIOSH, Pittsburgh Research Lab

KENNETH BULLOCK, MSHA

TONY BUMBICO, Corporate Safety Director, Arch Coal, Inc.

MATTHEW BUNNER, Safety Manager, Mulzer Crushed Stone, Inc.

ELLEN BYERRUM, BNA

BARRY CARLSON, Cargill Deicing Technology Business Unit

SCOTT CASS, Vice President, Sales and Marketing, ChemBio Shelter, Inc.

BRENT CHAMBERLAIN, Jerritt Canyon Mine

ELIZABETH CHAMBERLIN, General Manager-Safety, CONSOL Energy, Inc.

HARRY CHILDRESS, Cumberland Resources

JEN COOK, GAO

BOB COX, Kennedy Metal Products

BILL CROCCO, MSHA, Coal Mine Safety and Health

TOM CUSHING, Regional Manager, ZUMRO, Inc.

BONNIE DAVIS, Regional Safety Manager, Chemical Lime Company

PARTICIPANTS (continued):

MARY DOANE, Draeger Safety

JEFFREY DUNCAN, Director, Educational Policy and Development, MSHA

DAVID DYE, Acting Assistant Secretary, MSHA

MARK ELLIS, President, Industrial Minerals Association - North America

JEFFREY EVERSON, Foster-Miller, Inc.

SUSAN FELDMAN, Technical Director, Salt Institute

ROHAN FERNANDO, Draeger Safety, Inc.

BILL FLYNN, Product Line Manager, Biomarine, Inc.

LINDA FREDERICK, Scientific Program Administrator, NIOSH

ROBERT FRIEND, Acting Deputy Assistant, MSHA

PETER GALVIN, House Education and Workforce Committee

STEVE GIGLIOTTI, MSHA Technical Support

ROBERT GLATTER, MSHA, Educational Policy and Development

MARK GOOD, Kennecott Minerals

EDWARD GREEN, Crowell & Moring

ALEX GRYSKA, Ontario Mine Rescue Manager, Mines and Aggregates Safety and Health Association

GUNER GURTUNCA, Ph.D., Director, NIOSH - Pittsburgh Research Laboratory

WAISS HASRAT, MSHA

IAN HOULISON, Manager, Phoenix First Response

PARTICIPANTS (continued):

PHILLIP HOVIS, Vulcan Materials

JOHN HOWARD, M.D., Director, NIOSH

DAVE HUSSEY, President, Phoenix First Response

SARAH HUSSEY, Marketing, Phoenix First Response

MIKE JENKINS, Acting Deputy Director, NIOSH - Spokane Research Laboratory

REGINA JOHNSON, Assistant Editor, Platts

JIM JOY, Professor, University of Queensland

MICHAEL KALICH, MSHA, Coal, Division of Safety

BILL KENNEDY, Kennedy Metal Products

THOMAS KESSLER, MSHA, Educational Policy and Development

GENE KITTS, Senior Vice President, Mining Services, International Coal Group, Inc.

JEFFERY KOHLER, Ph.D., Associate Director for Mining - NIOSH

JOHN KOVAC, Res. Physical Scientist, NIOSH-NPPTL

KATHLEEN KOWALSKI-TRAKOFLER, Ph.D., Research Psychologist, NIOSH - Pittsburgh Research Lab

JEFFERY KRAVITZ, Ph.D., MSHA

JASON LAYTON, Arch, Inc.

CHARLES LAZZARA, Ph.D., NIOSH - Pittsburgh Research Laboratory

GARY LEWIS, Maysville Mine Manager, Carmeuse

GREGORY LILLY, Midway, West Virginia

GARY LONG, Shift Foreman, BHPBilliton, New Mexico Coal

PARTICIPANTS (continued):

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P R O C E E D I N G S

(8:00 a.m.)

MR. KRAVITZ: Let me introduce myself. Jeff Kravitz, Chief, Mine Emergency Operations for Technical Support. We also have Guner Gurtunca.

MR. GURTUNCA: My name is Guner Gurtunca. I'm the director of Pittsburgh Research Lab, NIOSH.

MR. KRAVITZ: Obviously, there has been a change -- Mr. Howard will speak to that later -- about Jerry Finfinger. It's something good about that. The first good thing today besides all of you showing up.

Okay. It's my pleasure to introduce David Dye, the acting assistant secretary for MSHA. David came to the Department of Labor in June 2001, where he served as deputy assistant secretary for the Employment and Training Administration, the ETA. After coming to Washington in 1983, David served as counsel to the Senate Committee on Commerce, Science and Transportation; director of external affairs for the Maritime Administration, the U.S. Department of Transportation; and counsel for the chairman of the Federal Maritime Commission.

He returned to Capitol Hill in 1991, where he served as chief counsel for the House Committee on Resources, chief counsel for the House Committee on Agriculture, and chief counsel for the Senate Committee on

Energy and Natural Resources.

Prior to coming to Washington, David served as professional staff to two committees in the Alaska Senate, as special assistant to the lieutenant governor of Alaska and as a regional and urban planner with the Department of Community and Rural Affairs in Alaska.

David received his bachelor of arts degree in 1970 for the University of Texas at Austin and was admitted to the Alaska Bar after graduating from the Franklin Pierce Law Center in Concord, New Hampshire, in 1979. He resides in Bethesda, Maryland, with his wife and daughter. Please welcome David Dye.

(Applause.)

MR. DYE: Thank you, Jeff. Can you hear me all right? Good acoustics.

Well, good morning, all of you, and thank you for coming today. I know that all of you realize the importance of this workshop and its potential for saving lives, and I'm grateful that many of you took the time to come here and share your knowledge and expertise with us.

I also want to thank the mine safety experts at both MSHA and NIOSH for providing their technical support and expertise to help us set up and run the workshop today, and a special thanks to Dr. John Howard for agreeing to co-sponsor this workshop, for his untiring efforts to make mines safe in this country. Thank you, John.

The mine emergencies that we've had this year have shown us that we in the mining industry must focus on better, safer ways to evacuate miners when there is a mine emergency. It's clear that we must improve mine escape planning and reemphasize that the first priority for any underground miner in an emergency should be quite simply to evacuate the mine. That is important and bears repeating often. There is no doubt, just get out. When your life is on the line, get out of the mine. This is an important point that often becomes obscured in discussions of how to deal with mine emergencies and rescuing miners who may be trapped.

The cruel fact of mine emergencies is this: Because of the catastrophic nature of most of these emergencies -- fire and explosion -- miners who are able to evacuate the mine immediately or shortly after the emergency begins are dramatically more likely to survive than miners who stay in place waiting for rescue.

Our mine rescue teams in this country are the best in the world. They must obey, like all of us, the laws of physics. They will not be able to enter the mine after an explosion or fire until it is safe enough for them to do so. By the time the heat and lethal gases return to the levels which permit them to enter the mine, those waiting for rescue will often, unfortunately, have perished from those very same hazards. We must continue to emphasize that miners must make every attempt to evacuate a mine whenever possible during an emergency.

MSHA has taken some additional steps towards instituting other measures to protect miners who may become involved in a mine emergency. On March 9, we published in the Federal Register an emergency temporary standard. This is only the third time in the history of the Mine Act that we have done this. The emergency temporary standard contains provisions applicable to all underground coal mines on self-contained self-rescuer storage and their use, evacuation and training, and the installation and maintenance of life lines.

We believe that the availability of supplemental SCSRs can increase the supply of oxygen, added life lines to guide miners along evacuation routes when visibility is poor, more frequent evacuation drills to condition miners to escape quickly, and proper training on how to transfer from one SCSR to another will help ensure that miners have a better chance of escaping from a mine emergency.

The ETS also includes requirements for immediate notification applicable to all underground and surface mines. Mine operators must notify MSHA within 15 minutes of determining an accident has occurred so that coordination of appropriate mine rescue and other emergency response can begin as soon as possible.

We are beginning to hold public hearings on the ETS throughout the country. The upcoming ones include April 24 in Denver, Colorado; April 26 in Lexington, Kentucky; April 28 at our headquarters in Arlington, Virginia; and May 9 in Charleston, West Virginia. We will also accept written comments until May 30, 2006. You can find more information about this on our Web site. We welcome and encourage your input, just as we need your input here today.

Today, in this workshop, we plan to take a look at mine escape planning, including the recent history of mine escapes, warning systems, and the use of self-rescue devices and life lines. The tragedies at Sago and Aracoma Alma No. 1 have given us impetus to take another look at the concept of rescue chambers in coal mines. Today, we will discuss emergency shelters, including the history and use of emergency shelters, how mine design has changed since the 1980s, shelter placement in the mine, configuration and construction, life support instrumentation, communication, training, and other issues.

However, advocates of emergency shelter should keep in mind that coal is a fuel, and in a coal mine a fire has virtually unlimited fuel to consume. While the story of the miners in the potash mine in Canada who waited for rescue in their emergency shelter had a good outcome, it should be remembered that potash is a fire retardant, not a fuel.

There are unique and special issues surrounding the placement of emergency shelters in coal mines, and we must be careful that technological innovation does not endanger rather than help underground miners.

One thing I hope today that is discussed in detail is the concept of expectations training, in other words, training to better prepare miners for conditions they may encounter during a mine escape, including traveling through smoke and knowing what they will experience while wearing an SCSR. Miners must also be trained at how to exchange a used SCSR for a new SCSR in potentially lethal atmospheres -- no easy task.

Now, just how important this kind of training can be was brought home to me by an unsolicited e-mail I received just a week ago today. A coal miner in Pennsylvania with 35 years of experience in various mines around the state wrote to me to tell me of training he had received at a mine fire school. As part of the training, the mines were subjected to a smoke-filled environment. I want to relate to you the most important parts of the e-mail.

"During this exercise, we were to don the SCSR and find our way out of a small maze that was built in a van truck. I must say that this was the single most enlightening experience of my mining career. I had been around small mine fires before but nothing where I had to simulate an evacuation drill such as this. Even though I knew that I was in no danger, I became somewhat apprehensive. I soon realized that even with all of this training that I have received over many years, I am not fully prepared to escape in a severe mine emergency."

His concluding sentence was even more powerful: "Please take this into consideration because, speaking from experience, we are not prepared."

That e-mail really hit home with me. I hope it does the same for you. It's clear that we must look into requiring obscured-vision safety training for miners and make a strong effort to see that we can provide it. I'm convinced that it will save lives.

Now, while we're discussing the issue of mine escape planning and evacuation here today, we must keep in mind that however strong our desire to keep miners safe and healthy, we must use the best, proven technology available. There is a great deal of new technology out there and as many great ideas to go along with that as there are technologies. But great ideas and spiffy, new bells and whistles that sound good and look good may not perform when the chips are down. Technology grows by leaps and bounds. There is something new under the sun every day.

Now, technology does have a central place in mine safety. However, we cannot afford to rely on unproven, untested technologies to save miners' lives. We have too much at stake.

Before I conclude, I want to remind you that Thursday and Friday this week, April 20 and 21, there will be a mine safety conference of international and national experts in Wheeling, West Virginia. MSHA and NIOSH will join the office of Governor Joe Manchin and the State of West Virginia in co-sponsoring the International Mining Health and Safety Symposium at Wheeling Jesuit University. This upcoming, two-day symposium will focus on different topics than this workshop that are no less critical to mine safety in this country. People interested in attending can register by calling the Robert C. Byrd Technology Transfer Center. Just ask anyone for assistance here if you're not already registered.

Once again, thank you for taking the time to come today and help us address this topic that is so critical to mine safety in this country. It's no exaggeration to say that people's lives are depending on what we can accomplish. Thank you.

(Applause.)

MR. GURTUNCA: I would like to invite Dr. John Howard to say a few words. Dr. Howard is the director of NIOSH.

(Applause.)

MR. HOWARD: Thank you and good morning, everyone. Welcome to Washington on this beautiful spring day. I want to thank you on behalf of all of my colleagues at the International Institute of Occupational Safety and Health and the Mining Safety and Health Program in Pittsburgh, Pennsylvania, and Spokane, Washington, for joining us here today.

In NIOSH, our job is to generate new knowledge and transfer that knowledge into practice globally, so it's entirely fitting that we're here today at the National Academy of Sciences to discuss the latest scientific advances and to push those advances into the future for miners throughout the globe. It's very important that you all know that at NIOSH we think that knowledge is more than just knowing. Knowledge is doing, and it's extremely important for us today that we realize that this is a workshop. We're all supposed to work today towards taking the knowledge that we have, identifying the knowledge gaps that we have, and move forward so that we can protect the safety and health of all miners.

It's very fitting that we're having this conference today here. This is the day that, at NIOSH, we celebrate the tenth anniversary of our National Occupational Research Agenda, and across town, at the L'Enfant Plaza Hotel, we're having a conference this afternoon to launch our second decade of the National Occupational Research Agenda. So it's extremely important that we hear from all of you today about what mining safety and health issues need to be added to that agenda, and I would invite any and all of you to participate in that agenda. The Mining Safety and Health Program has a research sector council that we would be happy to invite any of you to participate on, and if you need more information about that, please see me or anyone else here from NIOSH.

Lastly, I want to welcome our international visitors. This is going to be a busy week for all of us. As David said, we're having this conference today and another one sponsored by the governor of West Virginia later in the week. So this is a very important week for mining safety and health.

Again, I want to thank you for coming to our seminar today and our workshop today and invite you all to attend the West Virginia conference. Thank you very much for coming.

(Applause.)

MR. KRAVITZ: Thank you very much. A few more housekeeping things that you should be knowledgeable about. We're making a transcript of the proceedings today. That transcript will be available on the MSHA Web site. We are also going to put all of the PowerPoints from the presentations up on the MSHA and the NIOSH Web sites. I'm sure that we'll be doing that jointly in all aspects here.

We will also be identifying an agenda for research so we can feed that into whatever capabilities NIOSH has, depending upon their budget limitations, I'm sure, and we are going to jointly be doing a report for the whole conference trying to sum up and trying to identify those issues that need to be emphasized for the research agenda.

So we have a pretty ambitious proceeding after this conference, and we invite you to give comments along the way.

Our first speaker for the technical session this morning is Michael Brnich. Mike is employed with NIOSH, formerly Bureau of Mines, the Pittsburgh Research Lab, since 1984. For more than 20 years, he has worked in health and safety research where his principal interests focused on teaching and measuring mine emergency skills.

I've worked with Mike. He is a very capable person. Basically, he has authored and co-authored more than 50 technical presentations. Many of them are available on the NIOSH Web sites and go way back. Mr. Brnich holds a

B.S. in mining engineering from the Pennsylvania State University. He worked in the underground coal industry in various capacities, including a mining engineer, industrial engineer, safety trainer, shuttle car operator, and general inside laborer.

Mr. Brnich is a certified mine safety professional. He is a member of the International Society for Mine Safety Professionals and the SME and the National Mine Rescue Association. So, Mike, welcome aboard.

MR. BRNICH: Thank you for the introduction, Jeff, and good morning to all of you. My association with Jeff goes back many years, and we've spent a lot of time in the mines together on various issues on mine emergency response and self-rescue and escape.

Our presentation this morning is kind of the philosophy of mine escape, particularly as it relates to escape planning. This is an area that we had worked on for many, many years back at the NIOSH Pittsburgh Research Laboratory. Those of us who have worked in this area include myself, Dr. Kathleen Kowalski-Trakofler, whom you will hear speaking later this afternoon on psychological and training issues related to mine emergency escape; also Dr. Launa Mallett, Dr. Charlie Voigt, and Mr. William Weehagen back in Pittsburgh; and also a good, close friend and colleague of ours, now retired from the University of

Kentucky, Dr. Henry Cole.

Our principal work here has looked at issues related to mine emergency escape, and in the context of the work that we have done, we had the opportunity back in the early 1990s to interview 48 underground coal miners. Each one of those individuals escaped from one of three different mine fires that occurred in southwestern Pennsylvania.

We were particularly interested in the escape issues that these people encountered when they had to escape these mine fires. We weren't interested in particular details of the fire in terms of where it originated, what the causal factors were, but we were more interested in what these people go through when they have to escape such an event. This was something that no one, to our knowledge, had ever done before.

So we went out, and we interviewed these miners, and we asked them to talk about their escape experiences, and what we found globally was that their escape situations varied tremendously in terms of complexity. Some of these miners escaped with little, if any, difficulty when they had to escape the event, but others encountered some very complex escape scenarios.

When we looked at our workers, we were able to identify eight distinct escape groups, and these groups ranged anywhere from three individuals to as many as 10 individuals from one working section. At that time, these mines averaged in age at 42. They had an average of 17 years' mining experience. It was a pretty seasoned group of people. Most of them had at least 15 years' experience at the mine they were working at when the fire occurred.

We conducted these interviews. Two of us would go out into the field to interview these individuals. We interviewed them privately, pretty much one on one. These interviews lasted anywhere from 45 minutes to, in several cases, as long as two hours. We asked our miners to begin by telling us their experiences from the time they perceived that there was a problem until they reached safety outside the mine. We used a preconstructed interview instrument which we had particular questions we were looking to receive answers for, and then after the miners would tell us their story, we would go back and take a look at that questionnaire and fill in details where we wanted more information.

With the miners' permissions, we audiotaped each of these sessions and then had these sessions transcribed, and this resulted in over 2,000 pages of transcribed testimony. If you stack it up on the table, it's about this thick.

We then took all of the testimony, and the group of us involved in this began to read through all of this testimony, all 2,000-plus pages, and analyzed miners' responses for various things that they discussed.

One of the things we were able to do, and this is kind of the crux of what I'm going to talk about this morning, is we were able to construct what we call a "model of judgment and decision-making." That is the mental process that these miners go through when they have to escape. It looks like a pretty complex model, but when you look at it, it actually works out pretty simplistically.

Miners are always faced with what we call a nominal problem, the main problem they are dealing with, and that is the mine fire that's involved but factoring in what we call background problems and context filters, background problems being problems secondary to that main event: smoke-filled entries, toxic atmospheres, in some cases -- in fact, in a number of cases -- miners unfamiliar with the escapeways they had to travel.

Context filters; what are we talking about there? What we found, and this is typical human nature -- all of us do this -- is even though miners were beginning to receive cues that there was a problem going on, they tried to couch those cues in the context that this is something normal going on. For example, one miner we interviewed said, "I initially smelled work in my working section. I didn't think anything of it. I thought maybe the track crew was working somewhere out by and attaching bonds to the rail joints on the track rails coming in." So he never gave it much thought that something much more serious was unfolding.

People will then move into what we call the problem perception phase. That is where now they are starting to take all of the information that's coming into them -- it might be verbal information that's communicated, sensory information, smells, smoke, whatnot -- begin to put all of this together and make a diagnosis right here that there is a major problem going on. Once they have determined that there is something serious happening, now they begin this phase of looking at all of the possible options that they have in order to deal with the situation, but we find that other factors affect this, especially the diagnosis. Information uncertainty affects it.

Of the 48 miners that we talked to, two of those miners knew where the fire was. Two knew. Forty-six other miners did not know where the fire was. That simple lack of information had a profound effect on choices that people ultimately had to make. As a result, stress factored in. Complexity of the escape factored in.

Once mines looked at all of the options that they had, in some cases they had no choices and had to come back and do more diagnoses before they could actually make choices about how to proceed during the escape and then executed their decisions.

A very complex process that they went through, and this is not a one-time process. All during their escapes -- in some cases, these escapes were 45 minutes to 55 minutes in length -- this process continued throughout their escape process.

What were some of the things that we learned initially? First of all, we learned that people tended to perceive the problem in adequately at first. In other words, many people, even though they were starting to get important information, important cues, they really did not take these situations seriously. We found that the diagnosis that people made about what was going on was definitely affected by the warning messages that they received. In some cases, one group of three miners received a message simply, hey, back the machinery out of the working phases; we're going out. These three miners had no idea that there was a fire in the mine.

Choices that people had to make were heavily impacted by their knowledge of the mine and the quality of the information. In at least one of these mines, a number of the workers affected were working in areas of the mine that they had never worked in before, so they were not familiar with the working areas, and they were not familiar with escapeways.

We found that the quality of leadership affected decision-making. When we look in the context of a normal, everyday work day, we typically look to the supervisor as being the leader, and under normal production circumstances, they probably are good leaders, but what we come to find was when these emergency situations started to unfold, some of the individuals who may be good leaders on a normal work day were certainly not the best leaders when having to escape these fires.

And, finally, we found that the actions that these escapees took varied in quality.

Some observations we made: Without a doubt, workers will form a group. In no case did single workers come out alone. They always came together and formed a group, whether it was a group of three or a group of 10. Generally, people will actively participate in the process of judgment and decision-making. As we talked to these crews, these individuals, we asked them, what was going on on your section when you talked about this? Pretty much everybody had input in terms of what the crew was going to do. However, we found that individuals, even though they might have a difference of opinion, generally they would go along with what was decided.

A very important one right here: Miners will take risks to help each other, and that is something you have to be prepared for. It happens. What are we talking about? We're talking about miners at one operation, three of them, when the crew reached safety out by the fire, they realized one miner was missing. Three mines donned fresh SCSRs and went back in looking for that miner. It happens.

In another case, a miner went down. The crew decided, we're going to stay back with this miner; the rest of you go ahead. It takes a lot of guts to stay behind in smoke with a miner who can't make it out, but, again, we know that this happens.

Also we found that when leadership breakdown occurs, usually you're going to see leaders emerge. In fact, in some cases, some of the leaders who emerged were some of the last people that you would expect to emerge as leaders in the event.

Some recommendations we can talk about: One thing is that mines have to be aware of that time element involved. You don't have all day to procrastinate and decide what you're going to do because fires can move very rapidly. I think it's important to talk with individuals about the ramifications of keeping your groups together as opposed to splitting up. There are pros and cons to this. Again, you have to be prepared for the fact that people are going to help each other if a fellow miner has problems.

It's also good to look at individuals who identify leadership qualities, especially who could function as good leaders under emergency situations.

So let's talk a little bit about how all of this plays into escaping a mine fire. What were some of the background problems that people had to deal with? Well, again, they include smoke-filled entries, and these smoke-filled entries varied in situations where people had visibility as much as 30 to 40 feet but, in some cases, less than five feet. They had toxic atmospheres that they had to deal with. Miners had problems wearing their SCSRs. It wasn't because the SCSR didn't work; they did work. It's simply that miners did not know what to expect in terms of how those apparatuses work when they wear them, and, of course, leadership breakdowns occurred.

Context filters; again, as one miner said, he thought the track crew was out installing bonds at the track joints.

Another miner, who was a fire boss, he discovered one of the fires. He initially was walking the track entry, and he smelled smoke. He said, "I didn't think it was anything. I thought maybe we just had a hot conveyor belt roller on the conveyer." He said, "I continued on down the track." He went for another 1,000 feet before he hit smoke, and then when he hit smoke, he realized there was something more than just a hot roller on the belt.

Again, information uncertainty: a big problem for a lot of these people simply because they did not know where these fires were located.

Miner has to endure stress. David Dye alluded to this in his presentation, the miner who sent him the e-mail. For most of these miners, this was the first time they had ever been in smoke. In fact, of the miners we talked to, only two of them had ever been in smoke before, and those people were former mine rescue team members.

People didn't know how far they had to travel because they didn't know where the fire was. They didn't know if they had 2,000 feet to go or two miles to go. Again, miners had very limited knowledge of escapeways. Again, several of these crews, the mine had realigned crews, and the miners were sent to different sections that they had never worked on before, and so they were not familiar with that area. They had limited visibility.

I think a very important one is that miners encountered smoke in areas where they anticipated it not to be. A good example of this: One crew, a three-entry, longwall development section. Smoke had already made its way up on the section through the intake airway. The miners said, Well, we knew the smoke was going to be going back down the return airway. Ah, we're going to go out the belt line because we know the belt line is on a separate split of fresh intake air. Well, that crew started down that belt line, went about 600 feet, and all of a sudden hit a wall of smoke, and now these miners start to experience even more stress. They are saying, How did this smoke get in this belt line? It shouldn't be here. So some of the things that people have to deal with.

How about decisions? These are just a handful of the kinds of decisions people had to make. Who should lead the group? Is the foreman the best person to lead the group out or someone else?

I talked about breakdown of leadership. One crew started to escape. Actually, it was this crew that was coming out of six west mines here. That particular crew had a boss who was not familiar with that area of the mine. He finally reached a point where he said, I don't know how to get us out of here. The last person you would expect to step forward was the continuous miner operator. He had been a former fire boss or mine examiner. He knew the mine. He said, I'll lead us out, and that is who emerged as the leader.

Miners have to decide how to go out of the mine. Should they ride out on the man trip or personnel carriers or should they walk out? What routes should they take? Should they follow their designated escapeways, which is what we teach people? In some cases they did, but in other cases they decided to follow the haulage track. Some followed belt lines. Some even followed return airways.

Very importantly: When to don their self-contained self-rescuers? As I said, a lot of these miners didn't now where the fire was, and many of them delayed donning their SCSRs. In fact, they delayed donning them and, in some instances, traveled in smoke for about 15 minutes before they put the units on simply because they didn't know how far to go, and they knew they only had a limited supply of oxygen.

Whether or not the group should split up, and whether or not to leave a disabled miner behind. At one of these mine fires, a crew was coming up that was the crew that followed the belt line up. They traveled about 900 to 1,000 feet when one of their miners went down, a large man. I interviewed him. He was about six, three, about 300 pounds. He went down, and he said he just could not continue. Now you have to make a choice: Do you leave this miner behind, or do you leave? What this crew decided to do, they split the crew up. Three miners stayed behind with the downed miner. The other four headed out to try to get help, a very critical decision that they had to make.

Some basic conclusions we can come to: First, it's important that we teach our miners critical judgment and decision-making. Miners have got to know what they are going to have to be dealing with. We have to train our people to know our escapeways. When I worked underground, we would walk our escapeways regularly, and we always had miners who said, I don't feel like walking today, but guess what? This boy did. I knew my way out of that mine.

Conducting smoke training -- imperative. Anybody that's never been in smoke, you don't know what it's like. I've been there, a former volunteer firefighter. I know what it's like to be in heavy smoke.

Train miners in communication skills. This is very important also. We talked about communications systems. We talked about communication equipment, but even with the best communication equipment, if you don't give good information, that equipment or system is not going to help you at all.

Finally, identify potential leaders, especially people who would make good leaders in the event of a mine emergency.

I've given you just a brief overview. This is an area that I probably could give you about a two-hour workshop on, but we have published a document called Behavioral and Organizational Dimensions of Underground Mine Fires. I only have about four copies of it out on the information table. I do have one more copy in my satchel. It is available. All of the things I talked about plus other topics as well -- leadership issues, information uncertainty, miners' experiences in smoke, miners' experiences wearing SCSRs -- can all be found in this particular document. If you want a hard copy, if you see me sometime today, I'll be happy to take your business card and get you a hard copy, or you can come to the NIOSH mining Web site, and right here is the link that will take you right to the PDF. You can download the entire presentation from there.

Jeff, that's all I have, and if anybody has any quick questions for me. Yes, Bill?

BILL: Mike, I presume that thousands of copies of your study have been distributed in the industry. If these same questions were asked today, would you expect different answers?

MR. BRNICH: I don't think so. I think if we looked at other events, even the more recent events, I think we're going to see the same patterns. I really do.

(Applause.)

MR. KRAVITZ: Okay. One other feature we've incorporated into this workshop, we have John Gibson, Tim Rehak, who will be circulating up and down the aisles. They are going to be passing out index cards, if you raise your hand when you see them. John, could you stand up, and Tim? We're going to ask you, if you have any questions, please put them on the index cards. The final session will be a panel devoted solely to answering all of your questions. We'll try to do that as best as possible. If there is time between sessions, if we have some extra time, we'll try to sprinkle some of those questions in there, too.

Okay. Our next speaker is going to speak on the recent history of mine escapes, mine emergencies, a very knowledgeable person, Mike Kalich. Mike has been with MSHA for 19 years. Primarily, before that, he was with U.S. Steel for 14 years. He has a master's degree in safety from Marshall University, a bachelor of science in mine engineering from WVU. Certifications include the SME; certified electrician, State of West Virginia; certified mine foreman, State of Pennsylvania; certified assistant mine foreman, State of Pennsylvania; and certified mine safety professional. He belongs to the SME A-17 Committee for Mine Elevators, a member of the SME, and he is a former mine rescue team member, so very knowledgeable.

Mike, please come forward.

(Applause.)

MR. KALICH: I'm Mike Kalich, and I'm a senior mining engineer for Mine Safety and Health, and I will be speaking on the recent history of mine escapes, and I have six mines that I will be discussing, being Sago, Alma, Leverage, Willow Creek, Jim Walters, and Quecreek. The Sago and Alma discussions will be limited, though, due to the ongoing investigation.

The Sago mine explosion will be first. It occurred on January 2, 2006. This is a map of the mine, and it shows the mine entrance, the route of travel into the mine, and the two working sections being the two left sections and the one left section.

On the morning of the accident, the mine was preshifted, and prior to the men entering the mine, the mine was found safe to enter. At 6 a.m., the one-left and two-left crews entered the mine, the two-left crew being a few minutes ahead of the one-left crew, and the two-left crew had already entered the two-left section. As the one-left crew approached the entrance to one-left, the explosion occurred.

The one-left crew was able to successfully escape from the mine, and MSHA and the state and the mine rescue crews were called, and mine rescue crews entered the mine and systematically explored the mine and made their way to the one-left section where they explored the entrance to the one-left section. It was then determined to advance toward the two-left section. Again, the mine rescue team set up a fresh air base near the mouth of the two-left section, and exploration proceeded from that point.

The mine rescue teams found the first victim in this area near the mouth of the two-left section, and they then proceeded to the sealed area where the seals were constructed and found that the seals had been destroyed by the explosion. The mine rescue teams then entered the two-left section, and they discovered the man-trip car that had been used by the two-left section crew. They also found evidence of the SCSRs that had been opened and had been used.

The crews then proceeded toward the face area of two-left searching for the crew, and they subsequently found the crew in the face area behind a barricade. One miner was alive, and he was brought to the surface and transported to the hospital, and the other 11 crew members were found deceased in the face area, and they were also brought out of the mine.

The next mine I have is the Aracoma mine. This was a mine fire, and it occurred on January 19, 2006. The fire occurred near the Number 9 long-walk conveyor belt. The underground mine personnel proceeded to exit the mine. However, 12 miners were on the 11 head gate development section, and those miners also exited the mine, but they encountered heavy smoke, and two of the miners became separated from the group. Despite the initial rescue efforts, the two miners could not be located. The mine rescue activities began, and the two missing miners were discovered deceased on January 21. That's a photograph of the belt conveyor that was involved in the fire.

The next mine I have is Consolidation Coal Company, Leverage No. 22, and this was a mine fire that occurred on February 14, 2003. It occurred near the Sugar Run Portal Slope Bottom. The underground mine personnel were safely evacuated from the mine in this instance.

The fire reportedly started when a mine car loaded with garbage contacted the trolley wire. Miners at the scene attempted to extinguish the fire but were not successful. One of the miners received burns to his hands and suffered from smoke inhalation. All of the openings to the mine were sealed, and water was pumped down the slope in an attempt to extinguish the fire.

A map of the area in question. Coal was transported out of the mine by belt conveyor to the Sugar Run Slope Bottom. It is then transported by conveyor up the slope to the surface where the preparation plant is located. The track system is used for supplies, and the fire occurred in this area. As a mine car was being pushed into a side track, it derailed and contacted the trolley wire and caught the contents of the mine car on fire.

The next mine I'll talk about is Plateau Mining Corporation Willow Creek Mine. On July 31, 2000, a series of four explosions occurred on the D-3 longwall. While attempting to extinguish the flames behind the shields, another explosion occurred that fatally injured two of the miners. The entire mine was evacuated, and the surviving eight miners on the D-3 longwall received various degrees of injuries. Two of the miners were severely injured and could not be evacuated with the other miners, and they remained behind on the D-3 longwall section. That was done due to the injuries of the other miners. They just were not able to carry the other two miners out of the mine with them.

The mine rescue teams entered the mine, and they were able to rescue the two injured miners that were left behind. They also recovered the two bodies of the deceased miners.

The D-3 longwall section; it is a two-entry development, and the head gate is located right in this area. The initial explosion was believed to be in the head gate area caused by a roof fall that ignited methane and also ignited hydrocarbons.

The men on the section attempted to extinguish the flames but were not successful, and a second explosion occurred that fatally injured two of the miners. Another miner that was on the face was able to use his 10-minute SCSR. Everyone at the mine carried 10-minute SCSRs. He was able to don his 10-minute SCSR, escape off the face to the head gate area where a cache of self-rescuers was stored, and he was successfully able to transfer to a 60-minute SCSR and escaped the mine. Other miners on the section also used the 60-minute SCSRs. The two miners that were left behind also used SCSRs while they awaited the rescue from the rescue teams that came back in.

A personal emergency device system was also in use at this mine, and this system, the PED system, enabled text messaging to be transmitted to personnel underground. The use of this system was instrumental in alerting the miners underground of the need to evacuate. The miners in the active and remote areas of the mine at the time of the explosion were notified through the PED system and were able to safely evacuate the mine.

A photograph of the PED system. It's an LED readout mounted to the top of the cap lamp, and it says, "Everyone needs to come out. Fire."

The mine also had an approved SCSR storage plan. On the longwall, 60-minute SCSR caches were maintained on both the head gate and tail gate and on the man trips. All miners carried 10-minute SCSR units. Some of the miners on the 3-D longwall donned the SCSRs, as I mentioned earlier, and were able to safely escape or await rescue.

The next mine is Jim Walter Resources No. 5 Mine, and this accident, explosion, occurred on December 23, 2001. It occurred on the four section. While attempting to rescue one miner who was too injured to make it out following the initial explosion because he was left behind in the initial evacuation, 12 additional miners from various parts of the mine had assembled and were going to the four section. These miners were fatally injured in a second explosion. Of the 32 miners that were inside the mine at the time of the explosion, 19 escaped, and mine rescue teams entered the mine and rescued one injured miner who later succumbed to his injuries.

A map of the mine shows the portal entrances. It's a shaft mine, direction of travel to the four section. This is the area where the explosion occurred. A detailed map of the area shows the location of the battery-charging station was in this crosscut. The mine roof was initially permanently supported with 72-inch, fully grouted bolts, and what occurred here was the roof conditions were deteriorating in this area, and four miners were assigned the task to install additional roof supports, and they were in there building cribs at the time of the explosion.

The roof started working while they were in there, and a roof fall occurred at the battery-charging station. When the cave-in occurred, it released methane from the strata, and believed it was ignited by the battery. In the roof fall, the battery was damaged, and it resulted in an explosion, ignition to the methane. During the initial explosion, it damaged a number of the ventilation controls in the section also.

Just a depiction of the battery charger and the battery. As I mentioned earlier, the methane was released from the overlying strata, damaged the battery, and the arcing ignited the methane.

A photograph of the battery shows the damage. The lids, the covers, were damaged, which caused arcing on the battery terminals, which ignited the methane.

Two of the miners donned SCSRs and traveled out of the section to get help. The dust and smoke impaired their visibility, and a third miner also escaped off the section. These fellows were unable to carry the fourth miner out because of the injuries that the other miners had received, so he was left behind. They met the other 12 rescuers that were coming from various areas of the mine en route to the four section. Other miners deenergized the high-voltage power, but they failed to deenergize a block haulage light system that was used at the mine.

As I mentioned earlier, the initial explosion damaged critical ventilation controls and disrupted the air flow to the section and allowed methane to accumulate. The 12 miners that were traveling to the section to attempt to rescue the lone injured miner that was left behind, as they approached the section, it's believed that the block light system was activated and resulted in a second explosion that resulted in the fatal injuries to the 12 miners that were attempting the rescue.

This is a depiction of the second explosion, believed to have occurred near the end of the track on the block light system. It traveled into the face area and picked up coal dust and additional methane, and then the explosive forces traveled back out of the section to the front of the section and over toward the three east area and resulted in the fatal injuries of the miners that were attempting the rescue.

Nineteen miners successfully exited the mine, and mine rescue teams were organized, and a rescue effort was initiated. Mine rescue teams found one severely injured miner and three deceased miners located out by the mouth of four section, and the injured miner was transported to the surface, where he later died from his injuries on September 24.

On the morning of September 24, it was concluded that the missing miners could not have survived the effects of the explosions, and the rescue efforts were abandoned due to fire and other unsafe conditions. After lengthy recovery operations, the 12 remaining victims were recovered by November 8.

The last mine is the Quecreek Mine, and that was a water inundation, as I'm sure everyone is probably aware. It was opened into the upper -- coal seam. The coal is approximately four feet thick and accessed from four portals from a box cut.

On the afternoon shift, on Wednesday, July 24, 18 miners entered the mine. Nine miners were in the two-left section, and nine mines were in the one-left section, and the one-left section was approaching the old Saxman Mine, but the mining projections that were available indicated the mine was just developed to this area when, in fact, it was extended further into the Quecreek reserves. The one-left miners accidentally cut into the Saxman Mine, which resulted in water inundation. The water flowed into the mine and flowed toward two-left. The one-left miners notified the two-left miners that they had cut into water, and the two-left miners narrowly escaped the rising water, and they were able to make it out of the mine.

The one-left miners were unable to evacuate, and they took refuge in the face areas, which was the area that had the highest elevation in the mine. By 2:30 a.m., the water was reported about at this level, and eventually the water built to the point where it was to the outside of the mine and filled the box cut.

A six-inch bore hole was drilled into the mine to attempt to locate the miners, and at this time, contact was not able to be made with the miners, but an air compressor was installed on the surface, and compressed air was injected through the bore hall. It created an air bubble which prevented the water from rising to the level where the miners were located. A number of pumps were installed, and a major effort was made to pump the water out of the mine.

By Thursday, the water was at 1,852 feet and had stabilized, and we were gaining on the water. The water was starting to recede. A rescue bore hole was drilled near the six-inch bore hole with the intent of lowering the rescue capsule into the mine to be able to bring the nine trapped miners to the surface. During this time, there were some problems with the drilling. The drill bit had broken. It had to be removed from the hole, repaired, inserted back into the hole.

Of course, during this time, a second rescue bore hole was started with the thought that it may penetrate the mine before the first rescue bore hole. But as it turned out, the water, during the time that these rescue bore holes were being drilled, they had gained enough on the water where it was just about to the level where it was felt that it would be low enough where the miners could safely reach that rescue bore hole. In the interim, the water was again pumped down to a safe level. The rescue bore hole was holed into the mine. The miners were contacted. At that point, communication was established with the miners, and they were told to go down to the area where the rescue bore hole was, and they would be hoisted out of the mine on the escape capsule.

One of the many photographs that I'm sure you've all seen where the miners have been brought to the surface. That's one of the miners brought out of the capsule. Another photograph of another of the individuals. Again, another photograph of a miner in the rescue capsule that was successfully brought to the surface.

On July 28 at 2:45 a.m., all nine miners had been successfully rescued and brought to the surface. That concludes my program. Thank you.

(Applause.)

MR. KRAVITZ: Okay. Mike is on staff here in D.C. at our Arlington headquarters. John Radomsky is also on staff. He is the action investigation program manager for Metal and Nonmetal. He is a certified mine safety professional who holds a bachelor of arts degree from -- Scott College. Prior to entering college, he worked in shaft and slope development in underground coal mining.

In 1975, John began his career as a mine inspector for the Mine Safety and Health Administration. He was promoted to supervisory special investigator in 1984 and to assistant district manager for the South Central District in

1991. John was promoted to the present position as action investigation program manager in 2002. Please welcome John Radomsky.

(Applause.)

MR. RADOMSKY: Good morning. On behalf of Felix Quintana, who is the acting administrator for Metal and Nonmetal, I want to thank you for inviting me to participate in the conference this morning.

The program talks about recent emergencies in Metal and Nonmetal, and Jeff has asked me to speak about a couple of things this morning, kind of throw them out there for everybody to comment on and think about.

In the early seventies, in Kellogg, Idaho, there was a tragedy that occurred at the Sunshine Mine that resulted in the death of almost 100 persons who were trapped by carbon monoxide and smoke following a fire that initiated from spontaneous combustion. Metal and Nonmetal regulations, under 30 C.F.R. Part 57, contain stipulations in 11050 which deal with escapeways and refuges and in 11052 which specifically identify what refuge areas -- we'll take a quick look at 11050 first.

As I said, 11050 under 57 pertains to metal and nonmetal mines, but it stipulates that there must be two separate, properly maintained escapeways from the lowest levels which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed.

Now, as David Dye explained to us this morning, and we all realize, things are a little bit different with coal. Coal, being a fuel and very combustible, poses very different risks.

The regulation under B further stipulates that in addition to these two separate escapeways, if miners cannot reach the surface within one hour's time from their work area, then a method of refuge shall be provided for these miners.

11052 talks about some of the criteria for these refuge areas. There are not a lot of guidelines. However, it does say fire-resistant construction, preferably in untimbered areas of the mine, large enough to accommodate readily the normal number of persons, constructed so they are gas tight, provided with compressed air and water lines.

I think we can all be proud of the mining industry's efforts to improve safety over the past couple of decades. I know it's a pleasure to go into the mines today compared to when I worked in them more than 30-some years ago, and probably the greatest advancement to the prevention of fires in metal and nonmetal mines is the fact that we're using methods other than large timber sets to control the back and control the ground.

Presently, out of the 220-some metal and nonmetal mines that exist in the United States today, 18 of those mines are required to maintain refuge areas because the miners at the locations where they are assigned cannot reach the surface within one hour. However, as a credit to the metal and nonmetal folks in this country, 21 additional mines that are not required to maintain refuge areas have installed them in an effort to provide an extra measure of safety to the men and women that work there.

We're going to look at a couple of refuge areas that I've got JPEGs on. The first refuge areas that I'm going to show you are maintained at an underground platinum mine in Montana. Access and egress is provided by declines to the mining levels. Each of the refuge areas is located so that miners can reach them in 30 minutes or less. They are provided with water, air, telephone, tools and materials; however, there are no carbon dioxide scrubbers or food.

You can see that they mine on the 500-foot level, the 1,300-foot, and the 3,200-foot. The first refuge area that you can see is a portable unit, six feet wide, 10 feet long, and six and a half feet high, mounted on skids so it can be relocated. A close-up of the air and water line connections. This mine also maintains a leaky feeder communications system, and this is part of what they use to notify all miners in the case of an emergency.

Metal and nonmetal mines, as I said, we have a large variety. In the underground sector, we mine everything from gold to stone to talc to potash to trona to zinc, lead, salt. This particular refuge area is in an underground limestone in Kentucky that mines on multiple levels and uses decline entries for access and egress. But because there is limited egress from the lower development level, they established a refuge area.

Now, true, limestone is not combustible, but in today's modern mining we use large mobile equipment even underground: 75-ton haul trucks, large front-end loaders. These are big areas, and if this equipment does catch on fire, it generates tremendous amounts of smoke and heat, oftentimes burning for more than 24 hours before they extinguish themselves.

So the hazards in metal and nonmetal, although in a noncombustible ore body, for the greatest part, are still significant. When one of these fires does occur in a metal and nonmetal mine, because of the size of the entry and because of the ventilation configuration, ventilation is often disrupted, and smoke is transported in areas that normally are fresh air intakes.

This refuge area has not been used in any actual emergencies, as was the case in the one that we showed you from Montana. It contains water and air lines, a telephone to the surface, and it's located about 100 feet from the work areas. The inside of it is kind of spartan in appearance, but it's got the essentials that every miner would appreciate if his ability to get out of that entry were blocked by a piece of equipment that had accidentally caught on fire.

The third refuge areas that we're going to look at this morning are being maintained in an underground zinc mine in New York accessed by two vertical shafts. None of these refuge areas have had to be used in any actual emergencies to this date. As you can see, there is a portable unit at the 3,900-foot level and one permanent and one portable at 2,500 foot, and mining takes place on five different levels of this multilevel operation.

Toilet facilities, first aid supplies, additional bottled water, tools, and material are also provided by this mining company, which is more than the criteria called for in the regulation.

This is most typical of a metal and nonmetal refuge area that we're going to view. Most of them are built by drilling and blasting into the hanging wall or foot wall, establishing roof bolts and wire mesh, building a wall out of noncombustible material, putting a metal door on it, and meeting your air-tightness and fire-resistant requirement in this manner.

Now, the next picture is the inside of Refuge Area No. 3, which is similar to Refuge Area 5. You can see that they have blasted this in a large configuration, secured it, and have everything they need inside. Now, when they move from this level to another level, they will simply leave it. They may take the door if they have no plans to come back here because they can reuse that when they build the next one, but this is typical to the permanent types of refuge areas in metal and nonmetal mines in the USA: some of the supplies and equipment inside some of the refuge areas.

Now metal and nonmetal does not have a requirement that mining companies have to provide self-contained self-rescuers for their miners. The metal and nonmetal miners wear filter-type self-rescuers. The filter-type self-rescuers provide the ability to convert carbon monoxide into carbon dioxide by adding, through a chemical process, another oxygen molecule. There are a few metal and nonmetal mines that have elected to purchase self-contained self-rescuers on their own, but this number would be less than a handful.

Here is a look at a portable refuge area that's also in the same mine in New York. As you can see, they made this one themselves. It's kind of spartan on the inside but built air tight and would be welcome, indeed, following any emergency.

Let's talk about some recent emergencies. Fortunately, in metal and nonmetal we haven't, in the recent decade, had a situation where we have had a death following a mine fire or an explosion, but we have had what we consider emergencies.

On February 2, we had a mobile scaling unit catch on fire in Missouri. This mine uses a stench system where they dump into the intake ventilation air ethylmorcapidan, which is easily recognized by its odor, and that's the signal to get out. The miners in this case did not need to use their self-rescuers.

The scaling unit was not equipped with a fire-suppression system. The operator of the scaling unit had a hand-held extinguisher but was unable to put the fire out.

The next day, at an underground gold mine, we had a mobile jumbo drill catch on fire. Again, the operator was unable to extinguish it with a hand-held extinguisher. He went to the phone, called outside. The stench was dumped in the ventilation, and in 12 minutes all six miners working underground were able to evacuate. Two of the miners, however, did utilize their self-rescuer as they had to drive through smoke-filled entries.

February was a busy month in metal and nonmetal.

We had a mobile scoop unit catch fire at an underground salt mine that mines at a depth of 2,300 feet. This unit was equipped with an automatic fire-suppression system; however, the system was unable to put the fire out. This mine maintains and utilizes a leaky feeder communications system. All miners were notified immediately through the communications system. All 40 people working underground got out within one hour. Am I right, Barry?

BARRY: Yes.

MR. RADOMSKY: Thank you. The miners did not have to use their self-rescuers.

No matter what system we design or install, and no matter how well we train our miners, the key to being safe and preventing an emergency, I believe, rests with maintaining our equipment in A-1 condition: the elimination of hydraulic leaks, the proper maintenance of insulation on electric wiring, and a good preventive maintenance program that keeps our equipment in A-1 shape, including our fire-suppression systems, including our seal-monitoring systems. We wouldn't think of operating our personal automobile with a basic safety feature malfunctioning or nonoperative. Nor should we allow these conditions to exist in the mines where we work every day.

The industry is to be commended, I think, for the progress they have made. I think their record is very good.

However, I think there is still room to do a better job. We can do a better job as inspectors identifying and suggesting ways that you can strengthen your safety process.

Jeff asked me to talk a little bit about the Mexican mine disaster. I was not there; however, Felix Quintana, who is the acting administrator for metal and nonmetal, was there for a week, along with Chuck Campbell, who is a senior ventilation engineer with our technical support group. Who else did we have down there, Jeff?

On February 19, at around 2:30 a.m., a methane explosion occurred in an underground coal mine that's located about 85 miles south of Eagle Pass, Texas. They had been mining coal here at this mine for more than 20 years. The depth of cover, I think, was somewhere around 550 or 600 feet, as I recall. Eight miners were able to evacuate. Some had burns. Some had some fractures and minor injuries. Seventeen major ground falls were caused by this explosion.

On February 22, the Mexican government, through the State Department, contacted and asked if MSHA could possibly provide assistance. They needed some help with establishing the constant gas monitoring and also asked for help, some guidance and some input.

As you can see, this area was all mined out, and right in this area they had driven some entries and mined it out, and they hit this fault. When they pulled back out, they did not build any seals in here, and so whatever methane was being generated in this mined-out area was simply coming out in the mine atmosphere, and the red is the return entry, dumping into the return. Right in this area there were two belt tenders. This was a belt transfer point, and the rest of the 64 miners who were unaccounted for were working in these areas right here.

Now we're looking at a close-up of this mined-out area and the fault line. When MSHA folks got there a few days after the explosion, they said there were 60-some people working here in a frantic effort to dig through and make passable some of these entries that had caved in. The methane concentrations that our folks found when tests were taken ranged from 6 to 8 percent. They recommended that those people be withdrawn and that activity ceased. That's the decision that was made because of these gas concentrations right in here.

The red areas indicate where the major falls occurred that were totally impassable. The yellow areas indicate where the falls occurred that people could get past or over top of. As you can see, there was no possible way in those entries to get past those areas until those falls were cleaned up.

What complicated matters, according to Felix, was that most of the ground support in this mine consisted of large timbers supporting steel I beams, and when the explosion occurred, it knocked all of the legs out. The timber legs were blown out, and many ground falls occurred.

One of the things that was decided here was that they would drill a hole here and degasify some of this mined-out area, put permanent seals where you see the two black marks, and where you see the green, they would be erecting temporary seals or ventilation curtains. The idea was to block off that gas from migrating in there and to reestablish the fresh air and then to reestablish the ventilation controls that were blown out between the different intake and return.

As they progressed toward the location where the two belt tenders were known to be working, they had to clean up all of these falls in order to get entry, and the progress was very, very slow. Because of the political pressure, it was decided that they would not use mechanized means to remove this fallen material, that they would do this all by hand. So at this point in time, it's projected that it may take another nine to 10 months to totally recover those folks that are missing.

Okay. This is going to conclude my presentation this morning, and I thank you for your patience.

(Applause.)

MR. KRAVITZ: Thanks, John.

Next is Kobus Zyl from South Africa. I'm glad that you could make it, one of the few South Africans that could. He received a bachelor's in mechanical engineering in 1992. He is a member of the Mine Ventilation Society of South Africa and the South African Institute on Mining and Metallurgy.

He joined CSIR in 1994 and is currently research group leader for mine occupational health and safety. The current main focus of the group is silicosis eradication in South Africa, noise-induced hearing loss reduction, and ergonomics in the mining industry.

Past experiences include coal mine headings ventilation design for methane and dust control, design model implementation for success, and simulation of ventilation systems and various mining conditions. He is working on a tool for coal mining -- strategies, which we do a lot of here, and I can't say; a system for the detection and control of flammable gases in hard rock underground mines. He is also a manager of the Perbos explosion test facility, and a very interesting project he has headed for a long time, the self-contained self-rescuer testing facility at CSIR. Please welcome Mr. Van Zyl.

(Applause.)

MR. VAN ZYL: Thank you, Jeff.

Good morning, ladies and gentlemen. Thank you for this opportunity to present some studies in South Africa and being part of this workshop. Listening to the previous presenters, it would appear that the issues we have in South Africa are not much different from the issues that have been discussed here today.

Basically, my talk will just be an overview as a start-off for a discussion point of how South Africa can actually approach emergency preparedness and then response. In the talk, you'll see that there are three main focus areas in South Africa. Basically, as we said earlier, once you have an incidence of -- atmospheres, i.e., fire or explosion, you need to get the miners to a fresh air situation, which in South Africa is on the ground. Then there's two issues associated with it. How do you get miners to that fresh air situation, and then, thirdly, how do you get them out of it, underground rescue back to the surface?

Basically, in the talk, you will see it divided up into these three main areas. Discussing current practices; it's not in detail. It is just an indication of what South African practices are, as practices differ from mining after mining. Research that has been done in the past; you'll see that there hasn't been a significant amount of research, although there is a definite needs. And then also it is not a formal study, but in a discussion with mining owners and workers, what are the critical needs that South Africa feels we need to address in emergency preparedness and escape? And then just a couple of concluding points.

Basically, the South African mining industry is regulated by the Mine Health and Safety Act. This act requires that the mine operator has identification and a risk assessment and then develops strategies to mediate the risk. The point I'm trying to make is that fires and explosions are a different risk, the whole process in South Africa is risk based, so it is on the onus of the mine operator to prepare an emergency preparedness and response protocol.

In practice, what does it mean? As I alluded to earlier, we need to get miners to fresh air as soon as possible. In South Africa's case, they opted for underground fresh air. This is the case both for hard rock mines and also for our coal mines. It was decided about 20 years ago that the establishment of rescue bases as close to the working place as possible will be the best way for South Africans to approach the incidents of fire and explosions. The reason for it, as far as I can establish -- I was not a part of that decision -- was based on the changeover of self-contained self-rescuers. It was felt that it would be safer to don a self-rescuer and get to a fresh air base where from you will be rescued.

As I said earlier, this has three issues related to it. First of all, what are the design criteria for an underground fresh air base? Where do you put it? What equipment is required, et cetera?

The second issue is how do I get a miner to the fresh air rescue area? As we heard earlier today, exactly the same experience: smoke inundation, low to zero visibility, nonfamiliarity with the section, et cetera, et cetera. We've had various incidents in South Africa where people followed exactly the right procedure, donned their self-rescuers and then tried to reach a rescue base, where in some cases people were found literally four or five pillars away from the rescue base, which would have saved their lives. So this is a very big issue in South Africa: How do we get the guys to the rescue base?

And then, thirdly, once these guys actually reach the rescue base, how do you get them out? Fortunately, in South Africa, the mine rescue service has an excellent track record in getting people from underground mines. That's both for hard rock mines and for coal mines. Again, I have to say that the size of South Africa and the location of most of these shafts allow for that rescue brigade to be centralized and actually have a very effective impact.

First of all, if you look at underground fresh air basis, what is the current practice? Basically, in hard rock mines it is stated that all miners must be able to reach a rescue bay within 30 minutes. This is based on the prescribed duration of self-contained self-rescuers in South Africa. Just some basic requirements: Again, the Department of Mineral Energy, which is the custodian of the Mine Health and Safety Act, does not prescribe what are the requirements for a rescue base.

Again, as mentioned earlier, there is scope to improve exactly what must be in a rescue bay and where it must be positioned. Typically, you will find that there will be compressed air feed in the hard rock mines to supply fresh air. There must be water, communications, and first aid, and the size basically dictates the amount of workers that needs to enter into this rescue bay based on its position within the mine.

In coal mines, it's slightly different. Again, based on a 30-minute duration of self-contained self-rescuers, it is generally accepted that the rescue bay will be within 1,400 meters from any given workplace. I didn't put that into feet. I apologize. It was one this morning.

There are two types. You get fixed cubbies that are established and also portable units. The idea of the fixed rescue bay is that due to the shallowness of South African -- they will be linked to the surface -- which will supply the necessary communications, water, fresh air, et cetera.

In some cases, it has been found that due to the overlying strata depth, occurrences of lakes, et cetera, that these rescue bays could not be reached from the surface. Current practice in South Africa is to use oxygen candles. There is basically a chemical reaction that is started once the miners enter the rescue bay to supply oxygen for at least 24 hours. Again, this is based on the mine rescue service's indication that they will be able to reach any rescue bay from the shaft, given proper access, within 24 hours. Again, portable rescue devices, again, supply a 24-hour duration and mainly using oxygen candles, again, to supply fresh air.

Most of these portable rescue chambers are OEM designs, people taking the initiative and supplying a product to the mine where we feel that maybe the mine operator should have a bigger input into exactly what are the requirements of these portable rescue bays.

For the rest of this talk, I'm just going to focus on collieries as to currently what is the best practice. Research has been done in the past. As I said earlier, most rescue bay designs and layouts are enough, but even guidelines exist, so there is scope to actually improve the guidelines on what is required in a rescue bay. Related research has been done by the Mine Health and Safety

Council, which is a public-funded mechanism whereby mines pay a levy to the Department of Mineral Energy, and they put money available for research. Over the past 10 years, I could identify typically three projects that were specifically based on emergency preparedness and response.

Again, as I said, assessment of design of rescue bays in coal mines. What I've been saying earlier is that there is scope to actually increase what is required within a rescue bay. If you read this document, which was published about eight to nine years ago, it is very vague to what should be in a rescue bay and not clearly stating what must be in there in specific terms. We also looked at the feasibility of using radio-assisted location in rescue bays. Again, it was a guidance document. Currently, it is not practiced in South African underground collieries. Also, a manual on base practice for emergency response procedures; again, it's a very generic document, and we've found that in industry, if you look at the different mining -- each mine and mine operator uses its own interpretation of the work done.

Potential needs to be identified for underground rescue bays; as I indicated earlier, there are clear guidelines on the maintenance of rescue bays, the location of these rescue bays, again, the issue of sealing. Some of these mine operators are not convinced that the sealing mechanism used on their mines is proper. Again, they comply with the law and say, we have a rescue bay, and it's got air-tight doors. Again, how do we ensure that that is actually the case?

Some of the mines using oxygen candles as the main supply; the compressed air line is not favored because it's not used in collieries. There are issues around these oxygen candles catching -- being an exothermic reaction. They have also had incidents of these oxygen candles being stolen by the miners. Again, there's issues that need to be resolved there.

The issue of flame-proof or intrinsically safe, portable rescue bays; the DME states that no nonflame-proof and nonintrinsically safe equipment will be used closer than 800 meters from any working area in a fiery mine. This prohibits the mines from actually getting these rescue bays as close to the working place as possible, so there are some issues there that need to be resolved.

Again, the minimum design criteria for portable rescue bays; these are product driven instead of being driven by the requirements of the mining operators, and a significant issue is once we've entered the rescue bay, it's been sealed, and we've activated the oxygen candles, how do we get a miner that was not there when the team entered the portable rescue bay? There is a knock on the door. What do you do? You've got a limited amount of oxygen candles. Do you open the door? Then you most likely will significantly reduce the duration of your life support. So these are some of the needs that we feel that we need to start looking at.

Current practice around getting mines to rescue bays; I've divided this into two areas. In South Africa, we have what are called the "section waiting places." The reason for that is that from your section waiting place there are different guidance systems to get to the rescue bay. To get to these guidance systems or potential caches of oxygen-giving devices, all South African underground collieries are issued 30-minute-duration, self-contained self-rescuers.

What is unique, or what came to the fore through research, is that each miner is issued his dedicated self-contained self-rescuer. In the past, due to the shifts, three miners located a self-contained self-rescuer. During our testing, it was found that this practice reduces the durability and the life-saving potential of the self-contained self-rescuers.

This brings me to the next point. It was identified in the middle nineties that we need to be sure that self-contained self-rescuers will provide a 30-minute life-saving ability because all of our escape and rescue strategies were based on this. The DME then instructed that an annual testing program would be launched. CSIR was the custodian of this. It basically consists of a self-contained self-rescuer being tested on a mechanical lung, prescribed breathing rates. One percent of all self-contained self-rescuers deployed in South Africa currently go through this testing annually.

The success of the program has been significant, in that issues identified with refurbished units, issues identified with the composition of the chemical base polarization, et cetera, has been picked up through the program and has been addressed at the OEM level. So in South Africa, we are pretty convinced that if you are issued a self-contained self-rescuer, the likelihood of having a 30-minute life duration is very, very good.

Just touching on the test criteria for the self-contained self-rescuer, it's both on oxygen supply, CO_2 scrubbing and also on breathing resistance. The committee consists of a tripartite technical committee that oversees the testing and sets guidelines. The tripartite is the state, original equipment manufacturers, and labor. The committee provides, as I said earlier, technical guidance on issues that have been discovered. How long can one use a self-contained self-rescuer? Five years? Ten years? This program is busy answering these questions.

The current practice to get from the section waiting place to the rescue bay; two types of systems, the guiding rope system and audio systems, have been used in South Africa. The guidance rope is typically used all over the world with a cone and is currently the favored system.

A Moses system was used by one of the mining houses where an audio beep was sounded from the section waiting place to the rescue bay sequentially so you would follow the sound. Although the concept did work very well, the maintenance of the system proved to be too expensive and too cumbersome, and it couldn't be guaranteed that the system would actually survive an explosion or be functional in an explosion situation, so currently that system is not being used anymore.

Rescue bays are marked, both audio, visually, and physically. Audio, there is a siren that is fitted outside the door so if you get in the vicinity, you should be able to reach the rescue bay. Visually, reflective -- they have got strobe lights, et cetera. Also what they do is they hang a conveyor belt in the road. If you actually walk past the rescue bays in very low visibility, you will actually hit this, and hopefully you will know that the rescue bay is there.

Maybe just a comment is that it has been found, as I said earlier, that people actually did miss rescue bays. They were in the vicinity but could not locate it. Again, we need to relook at these systems that have been put in place specifically from a durability point of view. Some of the mines, being concerned with this, have a cache of long-duration units, 60 minutes plus, both chemically and compressed air, oxygen, that would ensure that people would be able to reach a second rescue bay in excess of two kilometers to try to alleviate this issue of looking for the rescue bay.

Research was done, again, by the Mine Health and Safety Council into the use of ultra-low-frequency communication to be able to communicate with miners after an incident. Again, this work was done six or seven years ago, but we've also looked at in Australia, and I see that it is also in the States, the PED system that needs to be investigated because communication, early warning, is one of the critical factors, we believe.

Also work that was done is how do you overcome the disorientation and visibility after an explosion? Basically, this research said that no matter how well you know your situation, if you're disoriented, and you're in zero visibility, you're going to have a problem to get out of the section on your own. In this case study, a miner that had been working in the section for 30 years was asked, and he said, I will get to my rescue bay within 10 minutes. They blindfolded him. It took him an hour and 40 minutes and a couple of bruises to actually find the rescue bay.

Need. In discussions with mining houses, this is the most critical area we feel that we need to start focusing our attention on. The biggest concern is that although most of the regulations require that quarterly escape drills be held, it was found unofficially that in excess of 50 percent, if not higher, of the people in the section when they are just blindfolded, when they are not subjected to the stresses, to the -- environment, if they are just blindfolded and say, please get to the rescue bay, only about 30 to 20 percent of these people will actually make it. Again, this is unofficial information by just talking to miners, and this is also a very, very big concern as to how do we ensure people get to the rescue bays.

Again, early warning systems, as we heard earlier today; the quicker you know there is a situation, the better your chances of survival. Again, when do we don our self-contained self-rescuers? Some of the mines do use the stench gas or aromatic gases. When it enters the air stream, once a guy smells this, there is no question. Don your self-rescue and go to your waiting place before the situation gets out of hand. There are some mines that employ from the surface where they actually stop the belt. On inquiry, the miner will find out there is an issue. We need to get out. Again, there is a 10-to-15-minute mine delay. There are mine communication systems -- the EWAC system is used by one of the mining houses. A very good system, but what is the human response once an emergency is declared?

Nonvisual against visual guidance; are we going to go for a system on audio, or are we going to use just the guide rope? Are we going to try to get a person a pair of goggles? Some of the mines are talking about getting infrared equipment. I don't know how feasible that is. But, again, human response: If you can't see anything, you start to panic. So these issues need to be resolved or looked at more carefully.

Again, we've heard today preparedness training. In discussions with teams that were evacuated or safely made it to rescue bays under emergency conditions, you will find that in the majority of cases an experienced brigadesman was part of their team, so there was no panic. It was exactly the same sort of training that was discussed earlier this morning by Mike.

Some of minuses. We need to incorporate a goggle within the self-rescuer unit that's belt worn. The question is, will it actually make a difference? Again, we need to look at the human response factor. If I can at least open my eyes, if it's not burning, even if I can't see anything, my psychological state might be much more relaxed.

Needs: To get from the section waiting place to the rescue bay, effective systems. Do we need to engage more than one system, and if so, how, and which ones do we focus on? Again, looking at the reliability of systems not only after a fire and explosion but also general maintenance that was also raised today.

Current practice of the mine rescue services; I'm not going to elaborate too much on it. The bottom line is the mine rescue services work very, very well in South Africa. Again, because of -- South Africa, the location of the mines. The system is volunteer based, and it's region and countrywide. It's an independent organization that establishes its own training criteria. It also is contacted in the case of emergency and responds professionally by calling on the brigades within that area. So the coordination is done by the Miners Consulting Service, mine rescue service itself, by calling on volunteer brigadesmen. These brigadesmen undergo a rigorous annual assessment, and at the age of 42, you're not allowed to be a brigadesman anymore. As I said, a very good track record.

Again, it's a system of continued improvement. The current focus is on human physiological response, specifically, working in heat environments. We're trying to get systems in place where they can monitor their own workplace. You don't want a brigadesman to go in and overexert himself and in the process get himself in trouble. Also, working in teams in low visibility areas is emphasized significantly.

I call these challenges more than needs. MRS; they are basically just advancing the current system. They are currently looking at the equipment they use, especially the oxygen supply units, the physiological response, communications, et cetera, et cetera. They are trying to incorporate all of the new technologies into being a more effective unit.

The biggest concern is the declining numbers of brigadesmen. People do not want to volunteer to become brigadesmen anymore.

In conclusion, the biggest issue, in discussions with the mining industry, is how do we get people when they are working in the section to the section waiting place to the underground rescue bays. I think this is the biggest challenge that we face in South Africa, and one of the critical things we started looking at is what is the current technology, base technology, available, but also how do humans respond to an emergency situation? In the past, a lot of technology has been used, but what would you or I do if faced with that situation?

Clear guidelines on basic practice need to be established, especially for rescue bases. Also, early warning systems need to be looked at critically, and evaluation of basic practices after an incident. When we have incidents in South Africa, if it is a success story, yes, we got them out, newspaper headlines, but there is no formal way of going back and establishing why we were successful or why weren't we successful.

I think that's also an area we need to start looking at. Near misses are not recorded. The successful use of self-contained self-rescuers is not widely reported. There is no official system in place. When self-contained self-rescues are done, was it necessary, was it not necessary, and what were the surrounding circumstances? So it's important to have a formal system in place to learn from this.

That's my presentation for this morning. Thank you, ladies and gentlemen.

(Applause.)

MR. KRAVITZ: Well, we set out for our first panel to set a research agenda to set the tone for this workshop, and I think they have accomplished that.

Mike started out talking about leadership skills, group theory, group work, evacuation through smoke, different types of training.

Mike Kalich and John Radomsky related several examples of mine evacuations and mine emergencies in coal and metal/nonmetal.

Kobus, I think you did an excellent job stating the training needs and the research needs that are going to be discussed further in this workshop.

So I think we're off to a good start. Please return promptly at ten-fifteen for the second panel session. Thank you.

(Whereupon, a short recess was taken.)

MR. GURTUNCA: Good morning, ladies and gentlemen. Welcome to the second session of the morning. The second session is about escape technologies. We have five speakers. The first presentation will be given by Dr. Jeffery Kravitz, MSHA, and Mr. John Kovac, NIOSH. Their presentation is about self-rescue devices.

Dr. Jeffery Kravitz is the chief, mine emergency operations and special projects for MSHA technical support. He is responsible for coordination and supervision of the MSHA mine emergency operations program. This includes operation and maintenance of MSHA's mine emergency operations equipment and resources. He is also the manager of MSHA's mine emergency unit.

Dr. Kravitz is responsible for all MSHA respirator approvals as part of the joint NIOSH-MSHA approval program for all emergency breathing devices used in mining. He is also responsible for the MSHA portion of NIOSH-MSHA investigations of problems involving self-contained breathing devices and filter rescue devices.

Mr. John Kovac is acting program manager for mining and construction at the National Personal Protective Technology Laboratory. For nearly 25 years, he has been responsible for research and development of SCSRs.

MR. KOVAC: Good morning. Both Jeff and I will be giving this presentation mostly because the relationship that earlier the Bureau of Mines and later NIOSH and NPPTL has had with MSHA has been a very long-lived one, and it's been a productive and constructive relationship.

Secondly, I look out, and I see a lot of old friends, and I will remark, we have been through a lot together, but much work remains to be done. With that in mind, I'll begin.

In the aftermath of a mine disaster, miners are taught to don their self-contained self-rescuers and make an escape from the mine. So what we're going to talk about today is some history of these devices, the long-term field evaluation, the kinds of training that's been developed, ongoing investigations of SCSRs recovered from Sago and Alma, and future actions that we will take in order to advance the technology.

In terms of history, prior to 1981, miners relied on filter self-rescuers. In 1981, the first generation of self-contained self-rescuers were deployed underground. Those devices, because of their mining application, have a joint MSHA-NIOSH approval, MSHA acting under the authority of 30 C.F.R. • 7517.14 and NIOSH under the authority of 42 C.F.R. • 84. Because of questions regarding the longevity of these devices, their reliability in a mine environment after long deployment, in 1983, both agencies began a long-term field evaluation which amounted to collecting about 50 self-contained self-rescuers on a yearly basis from underground coal mines around the country, testing these devices on a breathing metabolic simulator, and seeing how well they would hold up.

Because of the size of the devices, and what the photograph illustrates, we have a first-generation, FSR, and the second generation, the government underwrote the development of smaller, lighter-weight units which could, indeed, be worn, and that happened in 1989. By the year 2000, SCSR reliability, because of the size of the deployment -- there are roughly 50,000 units deployed out there -- MSHA begins looking at durability of the units, and the long-term field evaluation expands from 50 units a year to nearly 200 units a year, and we include 100 FSRs also.

And, lastly, in 2005, the National Technology Transfer Center at Wheeling Jesuit University, in conjunction with NIOSH and MSHA, sponsored an SCSR workshop.

Meetings were held twice in 2005 to identify technological options for future advancement.

The units that we have today -- the Ocenco EPA 6.5, a first-generation SCSR; the Draeger Oxy K Plus, second generation; CSCSR-100, second generation; the Ocenco M-20, a 10-minute device; the MSA Lifesaver 60, 60-minute-duration apparatus -- the MSA Lifesaver is no longer being produced, so the deployment in the industry today consists of the three, one-hour-rated devices -- the Ocenco, Draeger, CSC -- and some mines choose to deploy, in addition to one-hour units, cached underground, the M-20s, a 10-minute SCSR.

What the devices look like as deployed as they are about to be used; they all share common features. There will be a breathing hose with a mouthpiece, nose clips so that your lungs essentially isolated and depend only on the breathing gas mix being produced by the apparatus, goggles to wear a breathing bag, and oxygen storage. There are two kinds of SCSRs, and they differ in the way that oxygen is stored and released. They are chemical-oxygen units. Some people understand these as "chem-ox units," and they depend on a solid chemical, potassium superoxide. Potassium superoxide stores oxygen and releases it in a chemical reaction that depends upon the water vapor and XL carbon dioxide in your breath.

On the other hand, we have compressed oxygen devices, and their oxygen is stored as a gas under high pressure. There is a separate CO_2 scrubber, and that material is lithium hydroxide, a solid chemical.

A number of lessons have been learned over the 25-year history of SCSR deployment. Let me begin, first: Escape is the primary survival strategy. An escape means taking the miner, on foot and under apparatus, from the deepest point of penetration in the mine to safety. In some cases, more than one SCSR provider is needed for escape, but a one-hour SCSR does not mean one hour for every miner under every circumstance.

The actual duration of the units depends upon the miner, body weight, his age, physical fitness, the difficulty of the escape, how far the escape is, other escapeway factors in terms of broken terrain, whether he has to walk upright or has to crawl, and, lastly, but not of least importance, the miner's confidence in his ability to make that escape under apparatus.

A miner's confidence depends on three factors: quality, the fact that the units at the point of manufacture will perform as stipulated; reliability, that his unit will work when called upon; training, that a miner knows how to inspect and maintain the unit in his possession, and just as important, that a miner has expectations training, what to expect while wearing the unit, how it's going to provide him effective life support.

We know that sometimes escape is impossible, and miners, as a last resort, must emergency shelter and wait for rescue.

None of the SCSR deployment over the last 25 years would have been possible without partnership from our various stakeholders. We work closely with these individuals, with these groups. There has often been controversy, but reasonable people can always resolve these debates in a reasonable fashion. Without their support, though, this wouldn't have been possible, and they include BCOA, the NMA, Mineworkers, Steelworkers, all of the SCSR manufacturers, and, lastly, again, but not least, MSHA being the co-approver in this activity.

So where we stand is this: If there is any objective in deploying SCSRs in this country or, for that matter, any country around this planet, no miner should be forced to rely upon an SCSR that might be unsafe for an escape. Just as important, a miner must have confidence that his SCSR will work in an emergency and have the hands-on knowledge of how to use it. Escape means taking a miner on foot and under oxygen from the workplace to a point of safety.

Jeff now will speak on the long-term field evaluation and the ongoing investigation of units recovered from Sago and Alma. Jeff?

MR. KRAVITZ: Thanks, John. I'll put on a different hat here and be a speaker for a while. I volunteered to take the lesser of the parts here.

The protocol for the long-term field evaluation, which was started in the early 1980s -- 1981 when SCSRs were first put into mines -- we definitely wanted to track the reliability and the quality of the SCSRs, as John mentioned. We started doing this with the first-generation units and have continued that ever since. That program is about a 25-year-old program.

Basically, we sample units from all of the districts. Coal Mine Safety and Health Districts all cooperate with us to help select the mines. We replace the SCSRs using NIOSH funds for replacement units and make sure that all of the units that are collected pass inspection. Basically, it's the manufacturer's inspection. At first, people were getting the idea that they could get rid of their really beat-up SCSRs, and the first batches we used to get in and brand-new ones in return. That's not what we wanted. We wanted something that actually passed the visual inspection.

So we worked that out now, and we have someone who is very well trained to inspect all of the units to make sure that we get good units for the field, although sometimes things do slip through the cracks. Then we end up going to the lab and cleaning units up, and we find that really shouldn't have collected that unit in the first place, which is a finding in and of itself.

We measure the life-support capability using NIOSH simulator and man test to compare them to new SCSRs, and reports are published after that.

Basically, the collection is such that we try to collect from the majority of SCSRs in the field. According to the market share, CSE has a slight advantage. Sometimes we get more CSEs than anything else. In 2004 and 2005, we had 92 CSEs, 22 Draegers collected, 20 MSAs, 49 Ocenco, and 15 M20s, which are very hard to get if you have M20s in your mine. We have a very hard time getting them because one of the problems is it's hard to get replacement units for them, from the government's standpoint.

This is what the testing looks like. Basically, we have the metabolic simulator. NIOSH basically has refined that over the years. The device has shown good reliability, and NIOSH is now looking at incorporating that into new testing standards. Maybe John will say something about that later.

Also, we have your man test. A few units are tested on the man testing to basically utilize the devices on live people. People from our mine emergency unit, when they sign on, they also sign on to be volunteers for this type of work, and they have cooperated very well, although over the last couple of years, we've been so busy responding to mine emergencies, we have not been able to do as much as we would like to do.

Examples of the SCSRs we have actually seen in the field have sometimes come as a result of different investigations that we actually have seen. Basically, a hose was torn. We have a unit here, an Ocenco, that was collected. In the early stages, it actually had a seal that was split. Lifesaver 60; we found some KO2 in the breathing bag. It turned out to have faulty filtering material.

The EBA 6.5; we would find these with slight cracks and sometimes with big dents in the lithium-hydroxide canisters here. Those obviously should have been removed from service, but they weren't. And the M20; obviously, this one here has quite a few cracks. That was before we instituted the program to only collect units that actually pass inspection. We've improved that considerably.

There have also been some problems since '92. Basically, quality control was about 44 percent, and I'm happy to say that, based on our efforts and our increase in audits at our SCSR manufacturing plants -- we were doing them not on an annual basis -- we started doing it on an annual basis, and that has improved tremendously as far as what we're seeing that the manufacturers are doing. I think that the relationship between the manufacturers and the government has also improved somewhat because of our close relationship with respect to finding problems before they actually become big problems.

Reliability was a problem 38 percent of the time, and that's improved quite a bit. Training had also been a major problem. We have units as far back as Wilburke, where training was a major issue, and I think we're still seeing some training issues. With Willow Creek, we saw training issues that were related. When I went out there to do some interviews with miners who had actually utilized their SCSRs, we found instances in other places where they have actually had problems with training. Again, training is a major type of a topic that we're all interested in in this conference.

We started some new training types of modules. Basically, we want to distribute and evaluate new training which will ensure that the mine knows how to inspect his SCSR and how to use it in the event of an emergency. These modules are the direct result of an interagency agreement between MSHA and NIOSH. We have all of the units that John pointed out involved in these training modules. We've just about finished all but the MSA. The Draeger module should be up shortly. It's going through final review. We started out with CSE and Ocenco because they have the majority of the market and then we went to the Draeger and then the MSA, we saved for last because it has the smallest portion of the market.

Each module consists of a brand-new training video. The video goes through all of the donning sequences. It gives some expectations. David Dye was talking about expectations training. We try to get that in as much as possible. That was an issue that was identified quite a while ago, and I still think that we have a ways to go with expectations training.

Some of the new things: We're going to have to now come up with a revision to all of those videos because of the need of the extra SCSRs in the field, different caches that are out in different types of mines. We're going to have to develop standard procedures for actually donning an SCSR when you're actually wearing an SCSR or transferring from one SCSR to the next. It can be a major issue.

Mike Brnich is working on that with Charlie Voigt. I was talking with Mike today, and Mike says that they are getting close to a solution to that. As soon as they do, we'll do different types of field testing with that, make sure it works, and then we'll incorporate it into our new training videos and then into our computer-based training modules.

Computer-based training modules are on the MSHA Web site under "interactive training," and I encourage you all to visit that site. We also distribute the videos and all of the CBT, computer-based training, from our academy. Each CBT has an instructor's guide on it. It has various scenarios from the videos on them, too, and I think we're doing quite a bit of good work with those modules.

I've also been talking with Jeff Duncan. Jeff has an idea of incorporating that into professional mine certification, so when the next revision comes out, we'll be able to printout of the certificate. We'll actually have people who have trained on that type of CBT have a certificate that shows that goes towards the professional monitoring. So that might encourage people to participate in this type of training, as well as the traditional training that's required by our regulations.

Also, we have screen savers and stickers for those who are interested in computer toys like that.

MSHA distributes these to the different mines, and as I mentioned, the certification for the professional miner, I think, will add quite a new facet to this.

Accomplishments: So far, as I mentioned, CSE is completed, Ocenco is completed, Draeger is almost completed, and the MSA is getting close to being completed. The video is just in the final revision, and the CBT is about 75 percent.

As John mentioned, we were tasked by the investigation team at Sago to basically take a look at all of the SCSRs that were utilized. We have formed a team. We have established a protocol, and to do that, we have looked at all of the SCSRs already. Those who are interested have been invited to all of the different types of testing we've done with the Sago SCSRs, and we're at the point now where we're almost prepared to write up our report. That will be incorporated into the accident investigation report from the Sago.

The protocol consisted of a visual inspection assessing the breathing condition. All but one of the SCSRs was actually used. The one that was used was put on a breathing metabolic simulator, and that did go for one hour. At least, I can tell you that.

Life support was assessed using the simulator for that one unit, plus we opened up each unit, looked at the chemical bags, and tried to gauge how much oxygen was actually used from the chemicals inside that particular SCSR. And as I mentioned, we will be doing a report for that. John, the future.

MR. KOVAC: Can the situation be improved? Can SCSRs be improved? The answer is yes. It's not a matter so much of technology but the will to pursue that improvement.

We would like to see the units be made more rugged, reliable, be tested on the simulator, have ways of self-reporting to make inspections simpler and more direct. We would also like to see some sort of registration so we know where the units are deployed at throughout the mining industry in the event of a recall or some other corrective action. Rather than go into a crisis mode, we would simply react by dealing with those units which were damaged and seeing that they were replaced in good order.

We could simplify things. We believe that manufacturers, by just stipulating performance requirements, things would work better, users will have the best SCSRs available, and the government will have the means for effective and early discovery problems.

Meetings were held with our stakeholders at the National Technology Transfer Center under their auspices in June and December of last year, and two concepts were evolved. One was that of a hybrid self-rescuer. That would be a combination of a closed circuit device which either transforms or switches over to an air-purified respirator, the idea there being that sometimes in the aftermath of a disaster, the atmosphere inside the mine has sufficient oxygen for life support but needs to be scrubbed of carbon monoxide or other byproducts of combustion. Prototypes of the unit were, in fact, discussed. Some bench work, in terms of experimental design, has been done.

The other concept that was evolved was for a dockable or piggyback SCSR/DSCSR, and here, because of the requirement for deploying multiple units along escapeways, the idea would be, rather than making a transfer from one unit to another, in effect, removing the mouthpiece from the one that the mine is wearing, they will go over to a completely new unit. You would simply swap out life support capacity in an orderly fashion, keeping the respiratory system, the way that you're breathing, isolated from the mine air.

I need to remark that type of unit is already allowed under the current regulations, which permit a deployment of a so-called "1060 SCSR."

My intention is to pursue these, working in partnership with any or all of the manufacturers that would step forward with the appropriate prototype technology to see it forward for development.

And that, I think, is all that we have to say on all of this, so if there's any questions.

MR. KRAVITZ: We're going to be doing questions at the end, so if you have any questions, we'll be circulating the cards, and then at the end of the day, we'll be having a whole panel devoted to questions. If you guys can start -- index cards, write down your questions.

(Applause.)

MR. GURTUNCA: Thank you. In the second part of the session, the presentations will be about life lines and escapeways. We have two speakers, Dr. Charles Lazzara and Ken Sproul.

The first presentation will be given by Dr. Lazzara. He is a physical scientist with the Disaster Prevention and Response Branch, Pittsburgh Research Laboratory, NIOSH. He received a Ph.D. degree in physical chemistry from the University of Chicago and was a post-doctoral fellow at the Institute of Gas Technology in the area of combustion kinetics. He joined the Bureau of Mines, now NIOSH, in 1971 and has been involved in fire and emergency response research since 1979. He currently leads a team investigating procedures and technologies to enhance the safety and operational effectiveness of mine emergency responders, including rescue teams, fire brigades, and evacuating mines. Charles.

MR. LAZZARA: Thank you. I would like to highlight today some of the research work being conducted by NIOSH under its Emergency Response and Rescue Program. The goal of this program is to enhance the safety and effectiveness of mine emergency responders. Now, when we classify emergency responders, we're looking at our first responders, which are the miners themselves. The underground miners will most likely be the first affected or discover an emergency, and they are going to have to make some key decisions, such as communicating that information to others and whether they can deal with that emergency themselves with the resources they have in hand, for example, fighting a small fire with a hand-held portable fire extinguisher, or whether they need to evacuate.

We look at the second responders to be fire brigades. Several mines do have fire brigade members available, and they have special training in the use of breathing apparatuses and also advanced fire-fighting skills and equipment. So while other miners might be evacuating a mine in a fire, these teams or brigades would organize, get their equipment, go towards the fire site to try to get that fire in its early stages. They may use hand-held extinguishers, water lines, high-expansion foam generators, et cetera, to try to put out that fire.

In terms of sustained responders, we rely on our mine rescue teams. They have the capability, of course, of being under air for longer periods of time, and they have extensive training in mine exploration, mapping, rescuing, and also in fire fighting, too, if there need be.

I would like to focus now, at least, on some of our research objectives for those first responders. We have conducted and evaluated smoke evacuation exercises at operating mines, and this is to enhance the evacuation preparedness of the miners and mine management and safety officials, as well as improve the competence level of miners who might have to evacuate through smoke-filled entries. We are also developing, identifying, and evaluating technology to assist evacuating miners in smoke-filled entries, and, of course, this can improve their chances of a safe evacuation.

In terms of the smoke evacuation exercises, we do this in partnership, of course, with operating mines, and, in general, we'll have a group of 20 to 30 miners which we'll gather together and brief them on what they are about to experience. We'll show them some of the technology we would like them to evaluate during that particular exercise, and then we'll send them through several hundred feet of mine entry where the smoke visibility ranges from about five to 10 feet, and in that first section we'll just have their normal mine escapeway markers that they have in their mine, which are generally reflective materials or signs.

Then we'll give them some additional technology, and we'll send them through an area of around 700 to 1,000 feet long where the visibility ranges from one to three feet, and they get experience of how they can maneuver and manage to travel through a really dense, smoke-filled entry.

Now, this is a white theatrical smoke, nontoxic, of course, and in an actual situation the smoke, of course, would be very black due to a burning conveyor belt, coal, diesel fuel, tires, and that kind of thing, and also they would be wearing their self-contained self-rescuers in addition. In some of these exercises in some mines, we generally have at least one individual in the group that would don an SCSR and travel through the smoke so he could relate his experiences to the other miners that are involved in the exercise.

Since 2000, over 1,900 mine workers have participated in smoke evacuation exercises at nine mines. As one positive output of this work, one major mining company has recently purchased a number of smoke-generating machines so they can conduct these exercises with their miners on a regular basis.

The type of technology we evaluated included directional life lines. The one we used is shown here at the bottom for our work. Essentially, it's a quarter-inch, yellow, polypropylene rope. It is flame retardant. It does pass the modified motor vehicle safety standard 302 test. It has about a 900-pound breaking strength. We have on it these plastic directional cones, and these are the guides that make it directional.

Now, there has been some confusion out there about how they should be installed. The tips of the cones do not point the way out. The line is designed so that once you grab onto it, your hand glides over the cone, so you don't have to remove your hand from the life line as you make your way out. If you happen to be going in the wrong direction, which has occurred, your hand would be blocked by the cone, so you need to turn around and go the other way.

More recently, they have put out another type of life line which is replacing this rope with essentially an airline cable, and this is a steel cable which is covered with plastic. Along the life line, at 25-foot intervals or so, they also have reflective tape. These cones can be positioned at various distances. Generally, in our work, they are positioned at 100 feet along the life line, and we found it valuable that if you're approaching an obstacle, such as a man door, or, let's say, making a right-hand turn, you may want to put a couple of these cones close together, within three or four feet of each other, to make people aware that they are approaching an obstacle.

This is some of the other technology that was evaluated during these exercises: various types of reflective objects and materials, different colors; chemical light sticks of various colors; strobe lights -- that's a xenon type of strobe light and light-emitting diode type of strobe lights; and these hand-held lasers like the one I'm using here. This is a Class 3A laser, five milliwatts. Well, 532 nanometers is the wavelength. You can see you can go a long distance with this, several hundred meters. We've found this very useful in terms of cutting through the smoke, and when you hit a rib or an obstacle in front of you, you'll see the point. You almost would use it like a light walking stick.

Here you see one of the participants exiting the smoke-filled entry, and he has the aid of a life line, which he has one hand on, and you see the laser beam cutting through the smoke. He is also wearing a reflective vest.

So what do we learn from some of these exercises? What I have here is data we got from one exercise in a western coal mine where there were 219 participants or miners that went through this exercise with these various technologies. These are some of the questionnaires we give them in evaluating the exercise. This is the number of miners who responded that they strongly agreed to that statement, the ones that agreed, disagreed, or strongly disagreed. You always get one or two of these guys. I think he misunderstood the numbering system.

I learned something new from this exercise. You see the vast majority of the 219 agreed to that. Some of these, of course, were experienced miners that have been in the mine a long time. Others were brand-new miners that were just there for less than a year and have never experienced anything like this before.

After this exercise, I feel better prepared to travel through smoke. The vast majority, again, agreed to that statement.

Here we get into the evaluation of the technology and what they thought about it. The directional life line was useful for escape in smoking entries. You can see, based on the number of agreements, that this was the best advice in terms of getting them through a smoking entry where visibility was limited to one to three feet.

The laser was helpful for escape in smoking entries. Once again, we got a pretty positive result on that, and we found, of course, this green laser was superior over, let's say, a red laser in terms of color.

The strobe lights were useful in smoking entries. Once again, a fairly positive response in aiding them to get through a smoke-filled environment or leading the way through the smoke-filled entry.

Then we started going down in terms of popularity. Chemical light sticks; a fairly good response, but a number of disagrees. And then reflecting material; that generally ended up at the end of the list.

Some of the comments we received from these exercises: "Good exercise on what smoke-filled entries would be like." "A very helpful exercise." It was surprising that we had a number of those, and the fact that they should have had this exercise a long time ago in terms of walking through their escapeways because generally when they walk through their escapeways now, it's in clear air. "Green was the more visible of all of the devices." "The escape rope was the most useful." "The lasers helped the most to find the ribs. I don't think that the life line would last long, but it definitely helps a lot."

Travel time slows considerably a smoke, a good fact to consider when assigning -- space SCSRs. At least one mine we went to took that into account in terms of where they had their caches of SCSRs placed along their escapeway and realized the fact that if you did have to travel through a contaminated escapeway, you would have to put those caches a lot closer than they are now.

And we get some good ideas, too, from the miners, like placing strobe lights on the escape rope for better effectiveness in actual situations.

We are starting to look into the possibility of lighted life lines based on a couple of different technologies, such as electric chemaluscent wire. So you can picture that as a life line put inside a rope, for example, that could be lit during evacuation either by somebody evacuating or by a signal from the surface or various other types of LEDs or even bulbs encased in plastic.

In conclusion, the underground smoke evacuation exercises better prepared miners for escape through smoke-contaminated entries. Directional life lines were selected by miners as the optimum escapeway aid, and laser pointers and strobe lights were also found to be very beneficial.

We have an interesting report that we put out just recently the summarizes this work, as well as the work that we do with mine rescue teams and fire brigades also. That can be found at our NIOSH Web site, or if anybody would like to be sent a copy, just give me their card, et cetera. Thank you.

(Applause.)

MR. GURTUNCA: Thank you. The next two speakers are -- interesting. They have something to do with Navy. Their experience -- I guess, working underground has got some similarities to working under the water. We'll see what we can learn.

The first one is Ken Sproul. He is the chief, Quality Assurance and Material Testing Division at MSHA Approval and Certification Center in Tridelphia. Ken received a bachelor of science in electrical engineering from the University of Pittsburgh in 1971. He also completed graduate studies in electrical engineering at the University of Maryland under a fellowship program sponsored by the Navy Department. In 1980, Ken joined MSHA, Administrations Approval and Certification Center as an electrical engineer in the electrical power systems branch. In 1981, he was promoted to the position of chief, intrinsic safety and instrumentation branch. In 1992, he became chief, quality assurance division. He later served as chief, electrical safety division, before assuming his present duties as chief, quality assurance and materials testing division.

Ken has served as an expert witness in cases involving intrinsic safety. He has authored several publications and presented papers at a number of conferences and meetings related to electrical equipment in underground coal mines. Ken.

MR. SPROUL: Thank you very much and good morning. It's my privilege to speak to you for a few minutes about the evolution of MSHA's requirements for the use of directional life lines in underground coal mines, and I think it's totally appropriate that I was preceded to the podium by Dr. Lazzara because he has very well made the case from the research perspective of the effectiveness of life lines as an escape tool for coal miners.

Now, I have to confess to you, though, that as recently as four months ago, this was a subject that I knew very little about, but I've read in the program that I'm now considered an expert, and I guess that tells us that we shouldn't always believe everything we read.

But the good thing is that the subject is not really that complex. It's certainly not rocket science, it's not high tech, and there is not a need for a mastery of high-level mathematics to understand life lines. After all, we're talking about a relatively simple device. It's just a rope, but when it's used effectively, it just might have the potential to save lives, and that's what it's all about.

But even the simplest things can get messy if we don't focus on some simple principles, and so I'm going to do my best this morning to keep us from getting tangled up on the subject, and I'll try not to interject any more puns either.

Let me talk now about the evolution of the requirements for the use of life lines. First of all, I should point out that several states, and these are the only ones actually that I'm aware of, have mandated the use of life lines under varying conditions for a number of years now.

In West Virginia and Kentucky, life lines have been required in alternate escapeways when those escapeways are in return air courses. I'm sure the theory is that in most emergency scenarios, the event is going to be more likely to occur in by, and so if you're escaping through a return, it's more likely to be filled with smoke, and so it's more important to have life lines there.

You can see, though, that Virginia took the opposite approach, and they require life lines in all primary intake escapeways, and I'm sure their theory had to do with something like this, that you're more likely to select the primary escapeway as your first route of escape. So there's two different philosophies there.

Now, let's talk about what we've done on the federal level with MSHA. Prior to June of 2004, there really were no requirements in MSHA's regulations that mandated the use of directional life lines. At that time, though, the belt air rule became effective, and it brought with it the requirement that life lines be used in any air courses that are designated as alternate escapeways when they are ventilated by return air, not only for belt air mines but for all mines.

Then, as David Dye told us this morning, in the wake of the tragic accidents in West Virginia in January of this year, the agency has issued an emergency temporary standard under its authority in the Mine Act, and this is a relatively extraordinary measure, only the third time we've done such a thing. I'm not going to go through all of the provisions. Mr. Dye has already done that. But I want to focus on the life line provision.

This became effective on March 9 of this year, when it was published in the Federal Register. The requirements for life lines are contained in the ventilation section where the requirements for escapeways are defined. Here you see 75.380 defines the requirements for escapeways in bituminous and lignite mines, and there is a parallel requirement, which I won't show you, for anthracite mines as well.

But essentially, the requirements for life lines are these, and you'll see that they are primarily performance oriented. There is not a great deal of detail, but let's break it down and look at it one by one.

First of all, each escapeway is to be provided with life lines, and that means that MSHA's approach is to mandate the use of life lines in both the primary intake escapeway and the alternate escapeway, and certainly I think you can appreciate the theory here, that by having life lines in both escapeways, it does increase the opportunity for a successful escape, depending on the accident scenario that the mines are confronted with.

The directional life lines or equivalent devices are to be provided. Most likely it's going to be a rope, and Chuck has already shown you the polypropylene version of the directional life line, and here is the aircraft cable type, and you're welcome to see me later and look at these in detail, if you would like.

We did leave open the possible that there might be other equally effective means for achieving the same end, and in some mines in the more permanent construction of the out by areas, in the mains, for example, there might be a handrail that would be installed that could serve as a life line, so we didn't want to mandate that it be a rope. Some mines have asked if they could use leaky feeder cables or water lines or something of that effect. As long as it meets all of these requirements that we've established for life lines, we've said, at least to date, that that would be acceptable.

Now, they are to be installed and maintained, and I put an emphasis on "maintain" because if they are installed and forgotten about, they may or may not be available when they are most critically needed, namely, during an escape scenario. They are to be installed and maintained throughout the entire length of the escapeway, and, of course, the escapeway is actually defined in this same section in paragraph (b)(1), and you can read it there, that escapeways are provided from the working section all the way to the surface escape drift or to the escape shaft or slope facilities to the surface. So it's a continuous device that needs to be there for the entire length of the escapeway.

Here is an example of what I mean by a

performance-oriented specification. It's to be made of durable material, and we haven't specified what the material is or what properties it should exhibit, but clearly it needs to be strong enough to survive normal mining conditions, for example, the degradation that may occur due to humidity or heat. It should be available in an emergency when miners need them the most, and they should be, obviously, sturdy enough to withstand any intense physical use that they are put to during the actual evacuation.

They are going to be marked with a reflective material at least every 25 feet so that in those situations where there is adequate visibility, the miners' cap lamps can help them locate the life line quickly.

It should also be located in such a manner for mines to use effectively during an escape. The proper positioning, of course, of the life line regarding its height and accessibility become key in the mines being able to locate and use it. We would recommend that the life line be installed at waist height so that the mines can stay below the level of the densest smoke. There are tradeoffs, of course. It's easier to make the installation along the roof line, and some mines are electing to install that life line along the roof but on breakaway hangars so that if it were needed in an emergency, it could be pulled down to where if the mines either needed to stoop over or even crawl, they could do so.

Incidentally, a number of questions have been raised regarding this requirement and others that I've discussed already. We have developed a compliance guide that's posted on our Web site in the format of a question-and-answer format, and I would direct you there if you would like to see what some of the key questions are that people have been asking.

The directional indicators signifying the route of escape, such as the cones that have been demonstrated to you already, are to be placed in intervals not exceeding 100 feet. The purpose, of course, is to provide some tactile feedback to the miners who may not be able to see because of a dark, smoke-filled environment.

Now, there is nothing sacred about 100 feet. We could have just as easily selected another number, and there has been some debate about how critical this is. Obviously, it's not a precision number, and we have been advising our inspectors not to issue citations if the cone spacing is 101 feet or something of that nature because it's not that critical.

What's even more critical perhaps is to adopt something along the lines of what Chuck Lazzara suggested, that at intersections or places where there may be obstacles, overcasts, or whatever, there could be additional cones or some other device placed that would give some feedback concerning the situation.

Life lines are also to be securely attached to and marked to show the location of supplemental storage of SCSRs along the escapeways. If the miners need additional SCSRs to make the escape, they need to be able to locate them, and that's what this requirement is all about.

So here it is. It's a rope. At least, the prefabricated ones that are available commercially are, for the most part, these yellow, polypropylene ropes with the reflective cones, and here is the aircraft cable version of it. I know that at least one major mining company has reportedly elected to use the aircraft cable type in their out by areas because they believe it will be more durable and less likely to be damaged with mobile equipment, and I'm sure that's true. It is a little more costly. I think it's roughly twice as expensive as the polypropylene rope.

Here again is the direction-of-travel indicator, and it may seem to be counterintuitive, but that was the design, and we're recommending that people install it and use it that way. Theoretically, you could use it in precisely the opposite direction, if you chose to, provided the miners were trained, but because of movement of miners from one mine to another or even visitors and others that may come to the property, a uniform and consistent approach across the nation would be much better.

Here is just a page from one of the vendors' brochures. I chose to put this up here just so that you could see what it looks like when a life line is actually draped through a mine entry. Here is another vendor and some information from their Web site. There's actually at least three that I'm aware of now, and because of the newly created market, there may be others that will be coming along, but Cambria County Association for the Blind in Evansburgh, Pennsylvania, has been a major supplier of prefabricated life lines for a number of years, Boone Supply in Boone County, West Virginia; and then the newest one that I've learned about, in Logan, West Virginia: Mine Life Line.

Well, have you reached the end of your rope yet? If you're trying to escape through dense smoke in adverse conditions, reaching the end of your rope is a good thing because that means you've reached safety, and that's what it's all about, saving lives. So thank you for your attention.

(Applause.)

MR. GURTUNCA: Our last speaker before lunch is Mr. Ryan Webb, who will talk about emergency recreation hyperbaric stretcher. Ryan is a registered professional engineer, and he has a bachelor of science degree in civil engineering. He got this in 1993. He has got 10 years of experience with the design, construction, installation, test, and deployment of ocean systems. He is a U.S. Navy second-class diver, July-November 1994. Very good.

Ryan works for PCCI, and he is manager for acquisition and certification of the U.S. Navy's standard Navy double-lock recompression chamber system. He also manages the creation of a technical manual, including operating emergency and maintenance procedures; acquisition manager for the U.S. Navy's emergency hyperbaric stretcher. He provided technical expertise, project management, and liaison for acquisition and certification. He was a project engineer for the modification to a U.S. Navy underwater fibroscope, designed modifications to the underwater housing, light source, and camera. He also managed the subcontractors involved in fabrication of new equipment and parts.

MR. WEBB: Good morning. My name is Ryan Webb, as he said, and I work for PCCI, located just across the river in Alexandria, Virginia. We are the U.S. distributor for the SOS Hyperlight, which is called the emergency evacuation hyperbaric stretcher, or EEHS, by the U.S. military, which currently owns the largest number of these systems.

The EEHS, shown here, is a portable, monoplace, folding, hyperbaric stretcher used to provide hyperbaric oxygen therapy to injured personnel at remote sites. The contact information for both PCCI and SOS is shown here. If you would like more information on either the company or the equipment, please see me after the session or call Mr. Alan Becker at PCCI, and we would be happy to help you.

The EEHS allows first responders to an accident site to provide an on-site, hyperbaric oxygen therapy to injured personnel. This is important because in most cases where HBOT is to be used, the sooner a treatment is started, the better the results tend to be. There is now no need to wait two to three days to get a highly effective treatment for CO poisoning after an accident. The system is easy to assemble and simple to use. In an emergency, the patient is slid into the stretcher, the windows are installed, and a few hoses are attached by way of quick disconnects. These are sized to prevent an incorrect setup.

Once the patient is ready, the stretcher can be pressurized, and the treatment can begin. Once the treatment is started, the patient can be transported to a full-sized, hospital facility recompression chamber.

Because of the light weight and small size of the system, it is man portable and can be easily stored at a mine site or transported to an accident location quickly.

The Undersea and Hyperbaric Medical Society currently recognizes 13 indications for the use of hyperbaric oxygen therapy. Obviously, not all of them are applicable to the mining industry, but three of these indications certainly are. These are carbon monoxide poisoning, crush injuries, and thermal burns.

Carbon monoxide is a colorless, odorless gas that is produced as a byproduct of combustion. The CO binds to hemoglobin in red blood cells at the sites usually utilized to carry oxygen to the tissues. Hyperbaric oxygen accelerates the clearance of CO from the body, thereby restoring oxygen delivery to sensitive tissues, such as the heart and brain.

The Undersea and Hyperbaric Medical Society currently recommends HBOT for individuals with serious CO poisoning as manifest by transient or prolonged unconsciousness, abnormal neurologic signs, cardiovascular dysfunction, or severe acidosis.

For severe crush injuries, the rate of complication, such as infection, nonhealing of fractures, and amputations range up to 50 percent. When used with orthopedic surgery and antibiotics, hyperbaric oxygen therapy shows promise as a way to decrease complication from severe crush injuries. HBOT increases oxygen delivery to the injured tissues, reduces swelling, and provides an improved environment for healing.

HBOT should be started as soon after an injury as possible. A number of related conditions, including compartment syndrome and thermal burns, are also benefitted by hyperbaric therapy. Thermal burns, if not fatal, can cause disastrous long-term physical and emotional disability to the survivor. Especially in enclosed-space fires, thermal and smoke damage to lungs can occur.

Adjunctive, hyperbaric oxygen therapy has been shown to limit the progression of the burn injury, reduce swelling, reduce the need for surgery, diminish lung damage, and shorten the hospitalization time for the patient. These benefits are more apparent if therapy is initiated within six to 24 hours of the burn injury. Ideally, the patient should have three sessions within the first 24 hours and then continue treatment as directed by a burn therapy expert.

Indications for HBOT typically include deep, second- or third-degree burns that involve greater than 20 percent of the total body surface area and less extensive burns that involve the hands, face, or groin area.

Here is the Hyperlight. It is a foldable, portable pressure vessel which uses light-weight, composite materials to provide a safe treatment environment. The Hyperlight is rigid when inflated but when not in use can be folded up into two compact travel cases. The gas supply for the system -- this is not shown in this photograph -- can be provided by PCCI as an optional item or by the end user to their own specifications.

The system is rated at 30.5 PSI, which allows a full United States Navy Treatment Table 6 to be performed even in an unpressurized aircraft at up to 10,000 feet. It's 88 and a half inches long and 23 and a half inches in diameter. The weights shown here can vary, as there are some optional extras, which we'll come to shortly. This slide also gives you the case sizes.

This is a United States Navy team transporting a patient in the Hyperlight. The photo also shows the gas supply system. You can kind of make it out in the back. This is what the U.S. Navy uses. It has two bottles in it, one oxygen, one air, and they have probably already exhausted one full air cylinder in order to pressurize the system.

Here is a photograph of the two cases that the system comes in, and this is the control box. It contains inputs for both air and oxygen, and on the output side there are connections for a built-in breathing system, or BIBS, the main stretcher air supply, the main vent, and a pneumofathometer connection to allow the chamber pressure to be read at the control box.

This shows the stretcher folded into its storage container with the control box in its storage location on top. To prepare the stretcher tube for assembly, all you need to do is turn the storage container on its side and pull out the tube.

These are the contents of the smaller case. This includes the two windows, all of the hoses, and the regulators that would go on the gas bottles.

Standard items that come with the stretcher include BIBS, communications, regulators, handling straps, a timer, and storage containers.

These systems can be built to a number of standards if used internationally, but for use in the U.S. they should be built to the American Society of Mechanical Engineers safety standard for pressure vessels and human occupancy, or ASME PVHO-1.

These next couple of slides show the components that come standard with the system. This is another photograph of the control box, the two cases stacked, and then the components packed into the cases.

This shows a full system setup on the left-hand side, the penetration window in the middle, which is where all of your hoses from the control box attach to, and the unfolding of the tube.

Here are some optional items that can be purchased with the EEHS: The medical log, which is used to send material into or out of the stretcher during treatments.

Dome hinge protection rings should not be on this photograph. They are required by the PVHO standard, but if you're buying an international tube that's done to Lloyd's, they may have different rings around the outsides of the windows.

Gas cylinders and a gas cart are an optional item. The amount of gas varies depending on the treatment, and different users may want a different gas supply system. PCCI can supply a standardized gas supply package or can customize one to your requirements.

Some other options are oxygen and carbon dioxide analyzers, connectors for electrocardiograms, ventilators, or other monitoring equipment, lifting slings, and a second pressure gauge, which would be located inside the stretcher. This acts as a backup to the main gauge in the control box, and during air transport in an unpressurized aircraft, it will allow direct readings of the actual pressure inside the chamber.

The next couple of slides show this optional equipment and women, and then some other items that I haven't mentioned yet.

The drag mattress shown here, it's useful. It makes the treatment much more comfortable for the patient, and it makes entry and egress for the patient much easier, as well, especially for an unconscious occupant.

The internal gauge is shown here, and the window with the medical lock, which is at the other end from the penetration window.

The hyperlight emergency evacuation hyperbaric stretcher is a safe and effective way to treat carbon monoxide poisoning, crush injuries, and burns by using a small, lightweight, and highly portable piece of equipment.

Before I end today I'd like to read a short article from the Journal of Emergency Medicine regarding a treatment that took place recently in Afghanistan by U.S. military forces. I quote: "We report the first case of suspected carbon monoxide poisoning treated by a hyperbaric oxygen therapy by using a portable hyperbaric stretcher. A 40-year-old British man in Kabul, Afghanistan was found unresponsive in his apartment. Initial treatment consisted of oxygen by mask at a combat support hospital for several hours, with minimal improvement. Operational security and risk prevented his immediate evacuation to the nearest fixed hyperbaric facility.

"He was subsequently treated twice using emergency evacuation hyperbaric stretchers. According to the U.S. Navy Diving Manual Treatment Table Nine, the patient showed marked neurologic improvement after the first treatment, and experienced near-complete recovery before his eventual evacuation."

This case illustrates the practical use of portable chambers for the treatment of suspected cases of carbon monoxide poisoning in an austere environment.

Thank you for your time today. If there are any questions, please see me afterwards or fill out a card with the gentleman in the back. Thank you.

(Applause.)

MR. FINFINGER: I'd like to thank all the presenters for their excellent presentations. Now we would like to break for lunch, and we'll come back at 12:30 to hear the third session.

Thank you very much.

(Whereupon, at 11:30 a.m., the hearing was recessed, to reconvene at 12:30 p.m. this same day, Tuesday, April 18, 2006.)

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A F T E R N O O N   S E S S I O N

(12:30 p.m.)

MR. KRAVITZ: Welcome back this afternoon. We have been leading up to the rescue shelters portion of this workshop.

I've already mentioned some design considerations, touched on it briefly. This afternoon we'll get into it a lot more deeply, with the manufacturers and some other types of discussions on emergency shelters.

To kick it off this afternoon we have Dr. Jan Oberholzer. He's an alumnus of the University of Pretoria, the Wichestrand and Wineza. I know I'm murdering that, but you can correct that if you want. He has been involved with coal and other types of mining for over 30 years with production, technical services, management, and research.

For 15 years he worked for the Chamber of Mines of South Africa, a research organization. When he left South Africa, he was the Senior Coal Mining Consultant for CSIR, a Division of Mining Technology.

He is presently the Manager of Mining Research and Development at SIMTARS in Australia. He is published widely in his field, which ranges from mine productivity issues, safety and health, as well as the environmental side of mining.

He is a Fellow of the South African Institute for

Mining and Metallurgy, the Mine Ventilation Society, a member of the SME, and a life member of the American Society for Mine Rehabilitation and Reclamation.

Of importance to this meeting is that he was the Chief of Field Investigations of the coal mining of the Chamber of Mine Research Organization when he was a post-lobane incident work was done. We heard about that earlier from Kobus. And led to the introduction of self-contained self-rescuers and other rescue methods in South African coal mines.

So again, another wealth of experience. And please welcome Mr. Oberholzer.

(Applause.)

MR. OBERHOLZER: Ladies and gentlemen, I would like to discuss a few aspects of the design and installation of refuge chambers. I would like to do it at the end of basically some history we'd all like to go back to. And then secondly, considering that I've had the experience of doing it in South Africa and in Queensland, I would like to give you some of my experiences there.

When one talks about matters like this, one always harks back to the history. And I think one of the most important historical facts is the Coriaz mine disaster of 1906, which actually, for the first time, accepted that coal dust plays a significant role.

In a similar way, I think Slebon in 1993 pointed out to the use of self-contained self-rescuers in coal mines.

In 1987 a rather nasty accident where 177 people were killed due to a fire of insulation material in a gold mine almost mandated the use of self-contained self-rescuers in gold mines. In 1993, at precisely the point when the South African industry felt that they really almost knew it all, the Middlebult disaster happened, which led to the Leon Commission.

In 1995, six months after the Leon Commission's findings were accepted by all, Fowl Reefs managed to drop a locomotive down the shaft. It killed 137 people, which really made the Leon Commission's implementation mandatory in South Africa. It changed the whole scene of mining in South Africa, possibly the same way as Sago might change the scene of mining in America.

In Australia, in the Moura Number Four disaster, 1986, it only killed 12 people, but it was significant in that, at that time they still used filter self-rescuers. But at that point they found that the normal flame safety lamp wasn't suitable any more.

Moura Number Two in 1994 only had 11 people dead. They had filter self-rescuers, but this warden's inquiry led to the development of new safety standards.

It is a rather nasty little fact between Moura Number Two and Korea's 1906, something that very few people know. In 1906, 25 days after the whole mine was destroyed by a coal dust explosion, 12 people came out of the mine. Three days later, another person came out, and closed the mine four days after the explosion.

What I'd like to discuss with you today is how do things happen in South Africa. Why do we choose a refuge base? What was expected from them? And how Queensland, which has based some of their thoughts on refuge bays and on South Africa, and on some of the experience we have had, and on the present feelings?

I think we must understand how the coal mining environment looked in South Africa, 1983/84. The sections were long; they were distributed geographically about three to four kilometers. The sections themselves were about six, seven rows wide, and over a kilometer in length. It was mostly board-and-pillar mining, and there was up to six sections per shaft. We had to get coal out to feed the power stations.

The interesting thing was there were 30 people per section, on average. In other words, in the event of an explosion or an incident, you would have these people streaming to the shaft, trying to escape. I would like you to consider 180 people arriving at various caches of self-rescuers at different times, at different places.

If one looks at crowd behavior, very seldom are people killed in an indoor place like this when there is a fire. They get killed due to trampling or to other issues. And this is one of the issues why we decided to install refuge bays. And this was based in those days when we did this work, we did various scenarios. In those days it wasn't called scenario planning, it was called what-if.

We actually could not find an alternative solution to the identified problems. How are we going to divvy up extended breathing apparatuses to people arriving at different times at these places? I do not even believe that we could do it today.

So what we came up with was the best horse for the course at that time. We drew up certain general specifications, and we left it up to the mines to develop the details, for the very same reason as it was a horse for the course.

We came up with some generic issues, design issues. The first one was that it had to withstand an over-pressure event of 20 psi. If one goes into work that was done in the U.S. Bureau of Mines, work done by the people that did the atomic explosions, work that was done by a crowd called the McCracken Investigation in Australia, they found that at an over-pressure of 20 psi, you will have a

50-percent chance for survival.

That means that at 20 psi, you will have people that you can rescue. If you have a coal dust explosion where you start running into very, very high pressures, the chance of anybody having anybody to rescue was very small.

The other issue is that the first place that a person needs to go to, and this will be a refuge bay or whatever, needs to be within 600 meters. And this was due to the matters of disorientation that was found by gentlemen like Dr. Kilbloc (ph) or Mr. Funensberg (ph), because they found that even though you can get there within the 15-minute self-contained self-rescuer, possibly you wouldn't be able to make it due to disorientation.

Another issue is that your refuge bay needs to have a positive pressure inside the bay. And this is due to the way that you would have pollution into that bay from the sea air on the outside. Therefore, the doors had to create a kind of seal.

The other issue is that this refuge bay has to be well-signed or identified. We, even in those initial days, considered fencing your roadways off so you would have to lead your workers into that bay.

Communications to surface seemed to be very important, and has actually been proven afterwards to be even imperative. Provision of food, water, and sanitation facilities was seen to be important.

There needs to be air supply, because basically the problem that you're dealing with is a poisonous, toxic, asphyxiating atmosphere. So we need to have a supply of breathing air. We also have to have a positive pressure in that chamber, and we have to have a cooling of the environment.

Now, South Africa has a problem, and Queensland, for instance, not. There is no compressed air in the coal mines of South Africa. And I have an idea that there is not much compressed air in the coal mines of America. It's a kind of electric type of operation.

That's why, in South Africa, with its fairly shallow mines -- 150 meters -- it was actually very much easier just to drill a hole down and put a fan on top. Where this was impossible, oxygen generators or bottles was used. Unfortunately, when you use that, you do not have pressure in your refuge bay.

The other issue is the issue of communication. This is not only based on what we thought, but what I have seen subsequently in Queensland exercises. There is an immense need for leadership in the first-occurrence trauma. People need to have somebody to look at. The only problem is, I don't know how many of you have ever put on a self-contained self-rescuer. Anybody in this place that actually? You would know how well you can speak to your fellow human being when you've got that thing in your mouth. Communication comes to a grinding, sudden halt when you use self-contained self-rescuer.

In Queensland we use a thing called a compressed air breathing apparatus. This is where you've got a full face mask. Even at best, it's almost impossible. There's problems with one-way communication, and this is even if you phone or you get a message, the people up top do not know what you want to say, and sometimes disregard you.

And there's also a very strong need for a consolidation of acts. Once that initial panic and problems are sorted out, people need to just sit back and say how best do we carry on from here.

Now, there's some historic proof refuge bays have worked well in South Africa and have saved lives; elsewhere, as well. In Gloria Mine, after a fire, after four days, that got people out alive. At Emaswati Colliery, they had a major fall in the intakes. They had people captured behind it, and they got them out, very much similar to the Quecreek incident. Canada and Tasmania had one, with Tasmania seemingly, the Australians, anything they were really concerned about is they would have liked more finger biscuits.

(Laughter.)

However, we must realize one thing. And this is, if you look at the news and that, the fact that you've got a refuge bay does not mean you're going to save all the people. You're still going to kill people, because they might not just reach it.

In comparison to what I've just told you, I'd like to just share with you some aspects of the Queensland Mine environment. We have got a very, very low number of workers. Concentrated mining, high seams, on the order of four, four and a half meters, long walls, one development section, one long wall per mine. We have immensely high air speeds, which means that if you have a fire, you will pollute your mine in some cases under a half an hour.

We also work with a very much less prescriptive regulation. We work with a regulation which is based and supports risk assessment and risk management, which I think Professor Joy will tell us significantly more about this afternoon. It is a high emphasis on the management of risks and the use of safety management plans.

If we look at what came out of the changeover in the communication stations with relevance to this, and now this could be a refuge bay, it could be a halfway station, you can call it whatever you want. And this was made by the Task Group Four following them out of disaster. That the intervals at which these stations were should be based on the person traveling on foot. It should be ready, locateable, and accessible. It should resist low-intensity explosions, similar like in South Africa. It should be provided with restorable air, provided with robust communications, a method to determine toxicity and oxygen content of the air. And it should be sized capable for demand.

Now, in Queensland we have what we would call the level-one exercise, and it's held every year. And this is a very, very close simulation to a real disaster or catastrophe. The mines know who they are, they just don't know when it happens. And the way it is done is that it really, we come up with a scenario, we put it to them. We simulate everything. We ask them to do this.

But there has been some significant experiences out of this. And I've synthesized this into a few points. The first thing is that communications is a massive problem.

The second one is that the changeover to EBAs is a serious problem. For example, the very first exercise we had, which was the Southern Colliery, half of the people lost their lives due to the fact they couldn't open an Ocenco EBA with wet hands. Beautifully ergonomically designed, soft, smooth system. But the moment you take it with wet hands, you cannot open it.

In Australia, we have mateship. It is a sad fact of life that the self-escape and the self-rescuer means precisely what it says: you only have enough air to make yourself escape and to rescue yourself. When you start looking after mates, it becomes very difficult to take somebody out of a mine.

There is also the decision-making in the aftermath. You do not have time, and that is precisely when you need time. Traveling in escape routes can be beyond the capability of rescue crews. In other words, to get down and help somebody is too far for any rescue crew to actually get to.

The other one is, whether we like it or not, not all men are equal. They are neither physically equal or mentally equal. Sometimes the people that you would believe are the most suitable to rescue themselves are the most unsuitable. And even if it is a simulated exercise, things are not that easy. I have personally seen how people give up hope, and they actually stand there and realize that if this was the real thing, they would have actually died. It is an amazing thing to see that realization in a fellow human being's face.

The historical reality in Queensland is the following. That even though we have had exercises every year since 1998, we have identified issues, we made alterations, there are lists of issues that have come up, I believe that our industry is as highly committed as any industry could be. But we have unfortunately have had many successes, and even more failures, that shows where things aren't really well.

The unfortunate part, or very fortunate part, is that we have had no real emergencies against which we can test our present system.

Just some concluding thoughts. Refuge bays, emergency shelters, safe havens, changeover stations are basically all the same concept; some way for a person to go if he's going to run out of air. They are not easy to install, and they are not easy to maintain. There are, however, quite a few alternatives out there that the mine can use.

But I would like to point out that in my experience in both of these countries, that the refuge bay or these havens is not the solution. It is only part of a system of a very, very big system to get your people safe. These places must suit and fit in with a system at the mine.

To give you an example. The distance to your refuge bay in a mine that is two meters high will be significantly different to a mine where you've got four meters' height.

The bottom line is that a refuge bay costs money, it costs effort, and it costs other resources. The only reality of life is that if you do not spend that money, the alternative is that you will be held to task, say, if this person did not have enough air to breathe.

Gentlemen, I thank you.

(Applause.)

MR. KRAVITZ: Now we'll move you a little bit north, and we'll talk about Canada. Canadian experiences, Alex Gryska, graduated from Elliebурry School of Mines as a Mining Engineer Technologist in 1974, as an adult educator from St. Francis Xavier University in 1992.

He's a certified occupational health and safety technologist with the American Board of Industrial Hygiene, and the Board of Certified Safety Professionals.

Alex gained his industrial experience working at the Kerr-Edison Mine in Virginiatown and at the McKassa Mine in Kirkland Lake. He was responsible for ventilation and health matters while at the McKassa Mine.

He was more than 20 years at the Ministry of Labor. Alex worked in various positions, ranging from inspector, special investigations officer, trainer, mediator, advisor, regional program advisor, and ending his career at the Ministry as Manager of the Sault Ste. Marie District.

Alex has been associated with Imperial Mine Rescue in various capacities since 1975, and has been the Manager of Ontario Mine Rescue with the Mines and Aggregates Safety and Health Association, MASHA, since 2001.

And, Alex. Please welcome.

(Applause.)

MR. GRYSKA: Thank you, and good afternoon.

Refuge stations are an essential component of the emergency preparedness infrastructure at Canadian mines, regardless of what part of the country you may be in. Without doubt, they have resulted in saving countless lives.

Although most of our mines have refuge stations, there is no strict legislative requirement to establish them. Mine operators have found them to be an invaluable component of the safety infrastructure, and therefore integrated them voluntarily.

Ontario does not have any active coal mines; therefore, the hazards associated with our mining are somewhat different than what you folks encounter here in the coal mining industry. We do have some open-cut coal mines in the west coast, and I believe we have one underground coal mine operating on the east coast.

Our mines are generally quite large. They can extend for several miles laterally, and we will be mining as deep as 10,000 feet. We're not quite as deep as the South Africans; however, they are very deep mines.

Most of our mines are multi-leveled operations, where travel time from surface to the active workplace can be very significant. In some circumstances, it can take as long as an hour to get from surface to the active workplace.

These realities pose significant challenges to being able to ensure the safety of our miners, particularly in the event of an emergency. Mine emergency plans are developed by mine operators, and each plan is unique to their particular application.

In the event of an emergency, it's the intention to get workers out of harm's way effectively and efficiently. Although it's preferable to get them to surface immediately, it's not always possible, particularly when you take into consideration the vastness of a mine and their travel times.

In these circumstances, underground workers go to strategically-located refuge stations, and remain there until first responders are able to arrive.

Although we continue to focus on prevention, every year we encounter situations that require the services of our mine rescue crews. We have incidents where workers seek safety in refuge stations, and remain there until rescue teams are able to get them out from underground safely.

The recent incident at Esterhage Saskatchewan earlier this year is an example of how these refuge stations can work effectively. As you probably know, 72 miners sought refuge in underground stations, and remained there for some 30 hours, while rescue teams extinguished an underground mine fire and cleared the mine of toxic gases. Events similar to this, but perhaps not quite as substantial, have occurred, and have gone with minimal notice from the media or anybody else at our Ontario operations.

Our legislation requires that we have mandatory inquests into every event that results in the death of a miner. These hearings have resulted in numerous recommendations which have, in turn, resulted in legislative changes that have improved the quality of working life for our miners.

In 1928 we had a major underground mine fire at one of our gold mines, which our mine rescue teams were unable to handle the situation. Because of our limited resources, we requested the assistance of the United States Bureau of Mines Mine Rescue Teams, who responded and finally got the fire under control.

Thirty-nine miners lost their lives as a result of that fire. An inquiry was held to investigate the circumstances relating to this event, and it changed the approach that we took towards mine rescue. Numerous recommendations were made by the coroner's jury. Many of these have been transformed into legislation, which remain the framework that we have currently in place today.

Although not specifically referenced in a recommendation, refuge stations were first introduced at Ontario mines as a result of this tragic event. Mine operators recognized the value of providing temporary refuge for workers, and their existence continues not only in Ontario mines, but mines right across Canada. Pretty much in any province that you go to you'll find that there are refuge stations.

Our legislation does not require refuge stations to be established at all mines. However, it does state that they must meet a specified criteria where they are addressed by a mine's emergency plan. This approach allows for flexibility for mine operators to conduct a risk assessment and establish procedures which are appropriate for their particular situation. In all circumstances, it's the intent that the workers seek temporary refuge in those situations where they cannot get safely to surface.

And again, I have an excerpt from the legislation in Ontario where it specifies where a procedure, in case of a fire at an underground mine, provides for the use of refuge stations for workers, the station shall "be constructed with materials having at least a one-hour fire-resistance rating; be of sufficient size to accommodate the workers to be assembled therein" -- and the risk assessment as conducted by the employer would determine the maximum number of employees that might need to gather in that particular situation -- "be capable of being sealed to prevent the entry of gases; have a means of voice communication with surface" -- and that's normally done by telephone or leaky feeder systems -- "and be equipped with the means for the supply of compressed air and potable water."

We have developed a refuge station guideline in which we determined some of the good practices that need to be integrated into the system. For example, things such as obviously an air line, a supply of air.

Although until most recently, all of our mines, pretty much all of our mines had compressed air lines because we used pneumatic equipment for the purpose of operating drills and other pneumatic equipment. Therefore, air lines were present pretty much throughout the entire mine.

As far as potable water is concerned, it would be supplied to the refuge station.

Fire or sealing clay. Again, you can't get a perfect seal; therefore, it made sense to have available at each refuge station fire sealing clay.

As mentioned, a communication system. And I have some digital images of some of these set up that we will be looking at. So we will take a look at what we have as far as telephone system.

A system of lighting, seating, and emergency equipment, including stretchers, blankets, first aid kits, fire extinguishers, and miscellaneous supplies, which includes a copy of the emergency procedure, level maps, pens and pencils.

As far as the types of refuge stations that we have in our Ontario mines, we have permanent stations that come equipped with compressed air lines, we have permanent stations with the RANA system, Rimer Alco North American System, so they are the manufacturer. And basically, those are in those situations where we don't have compressed air line. For example, some of our deeper operations, they do not have compressed air lines. Therefore, what we need is to provide a self-sustaining environment. And portable stations with cascade air cylinders.

Now, we have an idealized sketch of a refuge station. You'll note in this case here there is just a single door. Basically, you have a drain in the floor with a P-trap in order to prevent gases from entering. Similarly, you'll notice on the sink, the same thing, we have a P-trap in there. Air and water lines. And as you can see, this would have been excavated out of rock.

You have seating that's provided for workers, copies of procedures, first aid kit, et cetera. Fire extinguishers, telephones, et cetera. And we have some refuge stations with a double door, so basically with an air lock. You have a door here, and a door there.

Now, as was mentioned by previous speakers, the issue of the air moving from the fresh-air side of the refuge station to the exterior, by having that air lock, a rescue team would be able to go through their pass properly. And the other things would have been pretty much the same.

Now, I've got a sequence of refuge stations photographs. Here's an underground refuge station outside entrance. You can see the way that they're marked up. You notice, well, you can't see the P-trap, but it would be under the floor. And you can see the door. Under most circumstances they come with a sill, so then the door will seal properly.

So this would be looking at the inside of the refuge station. You'll notice that we have a hot water tank, and there would be a sink in this particular one.

Again, as far as the refuge stations are concerned, under most circumstances, what we do is we use refuge stations as lunchrooms. It serves a dual purpose. So it gives the individuals a location to congregate. The other thing is it allows them to become familiar and be familiar with the installation. So in this case here, you'll notice there's a microwave oven, there's a stove, and there's a heating oven, along with a water fountain, et cetera.

As mentioned, fire procedures are posted in there. The workers, when they get an opportunity to familiarize themselves with the proper procedures, along with level plans for the operations, know where to go in the event of an emergency.

As mentioned, there's a stretcher, stretcher box, an eyewash station, an emergency list of occupants. So that's a list of individuals that would be working in that area. Again, it's necessary for somebody to take control in the event of an emergency; you can always cross-check against that list.

And again, we have, in this case here, we have a telephone system, along with telephone numbers that an individual would be able to call to inform them that there is an emergency that's ongoing.

As mentioned to you, fire clay. Fire clay is maintained in a bucket at each refuge station door, and it would be used to seal the door.

So we have air and water lines plugged in. And again, we put a silencer on there. We keep the air line cracked at all times in order to keep it under positive pressure, but at any given time that air line would be on.

The other thing is, what we do is we use ethyl mercaptan as a stench warning gas if workers were in the refuge station. This way here, with the air line being cracked continually, they would know if there is an emergency that's ongoing.

As mentioned, you can see that under most circumstances, our stations are going to be screened and bolted properly. We'll shock-treat the walls, and whitewash them so they're easy to maintain and clean. Also, they're all cement floors, in order to make sure that they can be kept clean. And as I mentioned to you, the refuge stations are used as lunch areas.

As I mentioned, some of our refuge stations are located in areas where there are no air lines that are available. We have one of our operations that is using this refuge one system. So basically what it does is, either you'll have oxygen that's supplied with cylinders, or it will be oxygen candles. You'll have a carbon dioxide cover; the air is passed through there via a fan, therefore giving sustainability to the inhabitants in a refuge station.

As far as refuge station procedures are concerned, we have procedures that require investigation of incidents where mine rescue teams are used. They can be real emergencies, drills, or simulations. Regardless, we gather information, assess it, and make procedural changes in order to make improvements where necessary. Over the years we've collected our learnings and developed a refuge station guideline, which is a compilation of information regarding good practice, and we make it available to our customer group.

When an emergency requires that a refuge station be used, a knowledgeable person needs to take control within the refuge station. Being sealed in a refuge station can and will cause enormous psychological implications on its inhabitants.

The person in charge needs to reassure workers, have them stay calm, and continually assure them that mine rescue teams will come to their aid.

Depending on the type of arrangement, they may need to use air sparingly. And that's why we keep the air header cracked slightly. If we're using bottled air, again, the sustainability will be dictated by the amount of compressed air cylinders that you would have there.

The individual needs to contact surface and inform them of the situation, assuming it's a mine emergency, and provide them with key pieces of information: the number of men that are in the refuge station, whether compressed air is available, whether workers have any injuries, and indicate that they are prepared to stay there if they, in fact, are.

Our mines are required to prepare an effective emergency plan that will protect the safety and health of our underground mine workers. The establishment of refuge stations does not replace the need for preparing an effective emergency plan, but rather is one small component of that plan.

Training is also a vital component of the plan. All workers must be trained in what to do in the event of an emergency. Training must address where workers are to go, and what tasks they need to perform. Mine emergency plans often identify refuge stations as temporary safe havens, and that's what they are is temporary.

The training should prepare individuals to take control, ensure the safety of refuge station inhabitants, and make appropriate telephone calls. Our organization provides standardized emergency preparedness training to supervisors, control groups, and employers, and helps them prepare for both fire and non-fire incidents.

Evaluating the emergency preparedness system and procedures needs to be done on a regular basis. We require that fire drills be conducted at each operating mine once per shift, per year.

Furthermore, we conduct audits of the system. We have developed a point-in-time evaluation tool which helps to assess the effectiveness of the emergency preparedness system. This tool looks at response times of first responders, and provides guidance as to the availability and adequacy of first responders.

Continuous improvement is critical to the emergency planning process. As mining advances, the adequacy of mine emergency plans must be evaluated. Are refuge stations still strategically accessible to mine workers, or do new refuge stations need to be established? These are questions that need to be answered on an ongoing basis.

Although we focus on prevention, and we continue to have fire and non-fire incidents at our mines, some of these have potential serious consequences. All the more reason that we need to learn from them, and make improvements as needed.

In conclusion, refuge stations are common at Canadian mines, and they have proven their worth time and time again. We need to remain vigilant and ensure that we do not strictly rely on refuge stations as being our emergency plan. They are, after all, only one component of that plan, and their use kicks in only after prevention has failed.

Are refuge stations an option to the safety and structure in coal mines? I don't think it's an easy question to answer. There obviously are some significant differences between our mines, which are metal mines, and non-coal. And that poses challenges to applying the technology.

Refuge stations have been invaluable to us in Canada, where we are primarily, as mentioned, hard-rock mines. I do believe, however, that by sharing our knowledge and experience, we may be able to distill and apply principles and approaches that may make mining that much safer for all of our workers.

Thank you.

(Applause.)

MR. KRAVITZ: Okay. The next speaker has quite a bit of experience, and I know him quite well. We used to work together for many years. I was working on the Mine Emergency Project, and he was with Foster-Miller, working on various remote-sealing projects and various robotics projects.

Randy Berry has been associated with Foster-Miller for 36 years doing contract research and development for private industry, government agencies, including the Bureau of Mines, MSHA, DOE, Navy and Air Force. He has two patents for underground mine equipment, and received MSHA permits for both intrinsic safety and explosion-proof instruments.

Different projects he's worked on over the last 35 years include robotics systems for the maintenance of commercial nuclear power plants, development of the mine rescue TV cameras and instruments to insert in bore holes, including a remote viewing system that was one of the predecessors of one of the newer types that are on the market today; health and safety studies for the U.S. Bureau of Mines and MSHA with a special emphasis on ventilation in mine emergency systems.

Randy was one of the co-authors on the 1983 published report on guidelines for rescue chambers, and that's what he's here to talk to you about today, among other things. And I think Randy's going to give you some good information.

So without further ado, Randy Berry.

(Applause.)

MR. BERRY: Thank you, Jeff. I'm delighted, having been preceded by several other speakers that have talked quite a bit about rescue chambers, to find that I don't think they're going to be able to call me a liar or vice-versa, so that's a little bit reassuring.

Before I get started, let me just give you a little bit more background about who Foster-Miller is, and why we are here today. What do I press here, anything? Like the arrow key? Will that do it? Enter, okay. All right. So far, so good.

Foster-Miller. We are a consulting engineering company. We are 50 years old this year. And we do contract research, as Jeff has already said, both for private industry and government agencies. And in recent years, we've done a great deal of work in robotics and in other automated systems.

For example, we, just in the past year or two, we have deployed, gosh, I don't know how many dozens, maybe 100 of these little robots here to aid our soldiers in Afghanistan and Iraq. The number one thing they get used for is for bomb detection and disposal, since it's obviously a whole lot better idea to have one of these things handling it than putting our men and women at risk.

These particular robots also come in other configurations. They can be equipped with all kinds of instrumentation. They have been used in hazardous material applications, where they have both sensors and then the arm that can pick things up and put it in a safe place.

But the real reason I'm here today is because back in the seventies and eighties, Foster-Miller did an enormous amount of contract research for the Bureau of Mines for MSHA. Jeff and I and John Kovac hung out a lot together in those days, when the Bureau had a lot of contract research dollars available.

And I won't go through all this, but I just want to give you an idea. Ventilation studies, a lot of different kind of emergency work, escape hoists, guidelines for metal and non-metal mines, how to use oxygen self-rescuers -- that was back in the day when they were still called oxygen self-rescuers. And they were too big to go on the belt, and we developed a whole set of policies, procedures, and suggestions on where they should be stored.

And finally, we did this report that I'm going to talk about today, guidelines for rescue chambers. It was published in 1983. And not to put Jeff on the spot, but I think both MSHA and NIOSH have PFD copies of it. It's a two-volume report. If you want some good bedtime reading, it runs over 100 pages each, and I'm going to try to distill that down to 20 minutes.

So as I say, my presentation is going to be a quick 20-minute summary of that report. And these are the various areas that I'm going to talk about. And again, there's no real point in going down the list. You can see it for yourself.

Before I get started, I just want to make one kind of motherhood-and-apple-pie statement. The United States is a little bit different than our colleagues in South Africa and Canada and Australia in that we don't have an official policy yea or nay for rescue chambers. And I think that's one of the good things about this today is we get some good dialogue going back and forth.

So what I'm going to talk about really is if you're seriously thinking about implementing one or more rescue chambers, here are the things that you should be thinking about. And the first thing, of course, is it is American policy now, and I think it always will be, that the first option is to get out, okay. And rescue chambers need to be part of an overall plan when getting out, for whatever reason, is impossible.

Before I get into some real details on the considerations for a rescue chamber, here is a list of the general major sort of general considerations. First of all, we found in our work that it is always mine-specific. And I think you're going to hear me use that term several more times. There is no one size fits all, literally in terms of the size of it, but also in terms of where it's located, how it's equipped. It really is a case-by-case situation.

The other thing is that for purposes of our study, we assume going in that the rescue chamber should be capable of being moved, not every week, but really for economics more than anything else. As a mine advances it's a dynamic thing, and we want to be able to reuse most of the components.

Finally, and I'll talk about this more later -- well, two more things -- explosion resistance is absolutely key. In fact, our design criteria were quite similar to what our Australian colleague mentioned earlier. That's essential. And we believe a positive air supply is essential. And again, I'll talk about that a little bit more later.

Our particular design will look somewhat similar to what you've already seen, a plan view of a room-and-pillar block-mining coal mine here. Kind of two ways to do it. Take a crosscut, and either put in two bulkheads, explosion-proof bulkheads, the advantage there being then that's accessible from basically two different entryways. Or, if you want to be a little more economical, you could actually either, you know, drill and shoot, or continuous mine or excavate a little bit just a dead-end chamber. And then you could just use a single bulkhead.

This project really came in two parts. I'm going to be reporting primarily on the second project. The first one that we had before we developed these guidelines was actually to design, build, and explosion-test an explosion-proof bulkhead. In fact, as I'll show you in a minute, because of different mine conditions, we actually designed, built and tested three different types of bulkhead. And once we proved that they worked, that they would survive an explosion, then we developed a whole set of guidelines on how to use them, how to implement them.

The explosion-proof bulkhead really sort of has four parts. One is just the structural piece itself, but that's just the beginning of the problem. Then you still have to have a means of securing it to the surrounding strata, the ribs, roof, and floor. You need a man-door that also has to be explosion-proof. And then finally just securing it there to keep it from getting blown out. That takes care of it structurally, but then you also need to be able to seal it to prevent noxious gases and maintain a good atmosphere inside.

And then the rib there, with just a note to myself to be sure to mention, the emphasis on all of our designs was to use off-the-shelf materials wherever possible. So there was really -- well, you'll see, there was very little that was custom-designed. It's standard structural shapes.

Here's that word mine-specific again that I said I'd mention again. The design that you pick, and in our case we did three different ones, was really a function of these two things. Okay, the size of the crosscut that you're barricading, and how competent the strata is.

Here is the first design. This probably would be the most generic of the three designs. The structural elements are 12-inch-wide channels, essentially. They are 12 inches wide, five inches deep, and they just bolt side to side to side. They are held in position -- this is for a mine that has competent roof and floor, okay. They are held in the floor by a trench in which you place these so-called footing boxes, and grouted them in place. The reason you have footing boxes is because when you get ready to relocate this bulkhead somewhere else, those footing boxes are grouted in, and they're going to stay. But the structural element you can lift right out and move.

Same thing on the roof. There's a header that's roof-bolted in. That in itself is not strong enough to withstand the forces, so you also have turnbuckles attached to roof-bolts.

And I have to apologize for the quality of the picture; it's almost 30 years old, or 25 anyway. But this is an actual picture of the assembly. All three of these were tested at the Bruceton Experimental Mine, as I mentioned, and actually explosions were set off. That's a picture of an in-place there. That man-door is a standard 24-inch pressure door again, so there's really nothing in this that's not off-the-shelf stuff, modular and reusable to the greatest extent possible.

Sometimes you've got a spalling roof, or for whatever reason the roof is not real secure. So this design depends only on the floor, by essentially using two footing boxes, okay, and then angled trusses going back there to support the top half of it.

And in this case, these are four-by-eight box beams every 27 inches. They support a couple of rails that go across, and then the final element are the corrugated steel panels. Now, these panels can overlap so that you've got some width adjustability. And they can also overlap this way, so that you've got some height adjustability.

Again, you've got the footings, but all the structural elements can be taken down. Everything is sized that it can be handled by two miners.

The final design is when neither the roof nor the floor is very good, and this is supported entirely by the ribs. This is an arch design, and this is all standard components from the tunnel lining industry. This is all tunnel liner plate.

The disadvantage to this design is, first of all, you have to do some fairly serious rib-sculpting in order to get enough support in there for that. And also, there's much less adjustability in terms of width and height. It comes in bigger modules.

So those are the three designs, and they all worked, okay. Now, what else does it take, besides an explosion-proof bulkhead?

First of all, and I was thrilled to hear almost unanimous agreement on this, is air supply. Our gold standard is a bore hole. And I don't think I need to spend a lot of time on that, because the other speakers have covered it very eloquently.

I will just say that not only does a bore hole give you an air supply totally isolated from the mine, but the next three items all become relatively less important in terms of storage requirements in your refuge chamber if you've got a bore hole, because you can get communications down, you can get water down, you can get limited first aid down. So to us, that's just the cat's pajamas.

Our second choice would be compressed air, and in fact, two independent compressed air sources. Probably something to think about for hard-rock mines, as speakers have already said, where it's available. Not going to see a lot of that in coal mines.

And finally, the third choices, as alluded to, would be bottled air sources.

I'm not going to spend a lot of time on the next couple of items, because again, the other speakers have talked about that. I will just say that some odd little things come up that need to be considered. And a good example of that would be, we've got this sealed-off thing in our case, where you have exposed coal on at least two sides of this. So issues of methane exuding, or other stuff becomes an issue, and you need to remember to keep the thing ventilated. I noticed our Canadian colleague mentioned that they keep their compressed air line cracked all the time for that kind of reason.

So that brings me to the last consideration, which is location methodology. If I had to do this slide over again, I would have put the last item first.

The number one criteria, I think, when you start thinking about where, if you're going to use refuge chambers, where you're going to put them, is it's got to be coordinated with the overall escape and rescue plan. And again, several other speakers have commented on that very eloquently. So I would move that to the top of the list.

And as part of that plan, you have to think in terms of storage of other self-rescuers. There has been talk today about training in terms of changing out from one SCSR to another. Okay, that becomes way less troublesome, obviously, if that can be done in a safe and secure environment.

So now I will jump up to the top, and I think this is the final time I'm going to mention mine-specific, but it is. It really is, once again, a case-by-case basis. There are some other small considerations, but they become important. You really don't want to put a refuge chamber in a low place in a mine where, when your pumps lose power, that that part of the mine is going to flood.

Surface access is real important, especially for us, because of the bore hole issue. I would suggest it's important even if you don't have a bore hole to start with. You really probably ought to think about having a rescue chamber underneath someplace that you will be able to get to should an emergency arise and you want to be able to reach miners that are taking refuge.

And finally, we say within one hour of the face. It should be located on the way out. We don't want to encourage folks to go the wrong way. And the one hour. We did a whole separate study, which time wouldn't allow me to mention here, but it's also available in the literature. We did some really comprehensive escape time studies with miners, without using any apparatus, using SCSRs, and also using a gadget that was about the size of an SCSR that was, basically it was a breathing monitor. It measured respiration rate, oxygen uptake, carbon dioxide generation.

And based on those studies, we developed recommendations for what we thought one-hour travel time was, depending on the scene, which again one of our other speakers has already eloquently mentioned. So that needs to be taken into consideration in converting one hour to a distance.

Conclusions. I noticed everybody had a conclusions page.

We feel like rescue chambers do have a place in an overall mine escape plan. It's not to say that you have to have them, but I think it's another tool that we've got in the arsenal to look at. And again, it has to be done in the context of the overall mine escape plan.

The other thing that I mentioned is that our report is 1983 dated. It would be great to kind of update and reevaluate that. And I feel like we're going a long way on that today, especially with the international speakers, and hearing about what other people are doing from around the world.

The other thing I'd say in that respect is that even in something as mundane as rescue chambers that are all structural steel and explosion-proof door, there are technologies that obviously do have a major impact on them. Communications, power supplies have changed a lot in the 20 years since we did this report. Positioning technology, being able to locate people is so much better. And drilling technology has gotten a lot better, which impacts being able to get in and rescue them.

And finally, just for the mechanics of the system itself, I think we've got improved materials, whether it's lighter-weight alloys or composites, and improved sealants and adhesives to seal off the perimeter of the bulkhead.

So I thank you for the attention. It's been a pleasure to be here today.

(Applause.)

MR. KRAVITZ: Okay, our next speaker isn't here today, he's in Kentucky. And by the goodness of our technology hopefully, we'll see if he's there.

Bud, are you there?

MS. MEYER: Well, actually it's Janet Meyer who's here. Bud has a very sore throat, and I'm going to be talking for him.

MR. KRAVITZ: Okay. Well, Bud couldn't be participating in the conference due to surgery. And now Janet, who I hear is a radio announcer, is going to take over for him. So I think it's a good choice.

Bud Meyer lives in Frankfort, Kentucky with his wife, Janet. He has over 50 years of experience designing rockets for the Air Force, DOD, and NASA. So where Ken Sproul couldn't find a rocket scientist, I found one.

(Laughter.)

MR. KRAVITZ: A real one. During that time he served as Battalion Chief on a northern California volunteer fire department, involved in mountain search and rescue before GPS. And that's interesting.

He is a current member of the International Association of Fire Chiefs, and acts as an advisor to the Volunteer Fire Departments of Kentucky. He founded, as Chairman of the Donald C. Hogate Foundation, to provide and champion outdoor recreation facilities for the physically and mentally challenged.

He could not be here today, as I said, because of surgery. And we will hear his talk, and I will be changing the slides. When you're ready to change slides, just let me know, and I'll do it as you see fit.

Okay, Janet, you're on.

MS. MEYER: Well, thank you. I want to say hello to all the distinguished panel members and guests, and offer you a very good afternoon from here in Frankfort, Kentucky. We really do appreciate this opportunity to be part of this workshop.

Because Bud is not able to speak very well at the moment, I'm going to try to voice some of his words. However, in the interest of time, as well as my hesitations with some of this, we're going to show you the slides that are going to be on MSHA's website, so there won't be a great deal of need to go over much on the slides themselves. You'll be able to access them yourselves later. And if you have any questions at all, you can, of course, call Bud in a day or two. And you can also email him with any questions you might have. He can handle email at any point. So he'll be glad to talk with you electronically.

Slide one. This is simply an introduction to the presentation. Bud has taken an integrated systems approach to the miner safety issue, and he's outlined a pilot project concept that involves technologies that encompass high- and low-tech approaches.

Now, slide two names the project, PPFIT.

Slide three lists the three primary PPFIT missions.

On slide four we introduce the elements of PPFIT. And I hope we did get your attention.

MR. KRAVITZ: Yes, I think you did.

MS. MEYER: Slide five suggests the disciplines to be included on the team effort. Any successful pilot project will call for a balanced mix of intellectual capital, strong leadership, specific marching orders, money, and perhaps some temporary waivers of regulations that may unintentionally set up institutional barriers to new technology.

Slide six shows the only marching order needed.

Slide seven lists potential funding streams. Any technical talent will need sustainable funding.

Slide eight lists the priorities for the team action. And these are the problems for which we're seeking a solution.

Slide nine addresses the first listed priority. Now, early detection of the known hazards can actually provide time to escape those hazards. And we think that Argonne may have the answer with their miniature sensors that can drive an audible and strobe alarm.

Slide 10 suggests that particular leaders arrange to visit the various sites of safe refuge, to study them, see how they work, and report their findings to the team.

Slide 11 names two experts in the field of extended breathing air supplies.

And slides 12, 13, 14, 15, 16, and 17 show where this technology is embedded in government and private sectors. Now, there are viable solutions available, and a working prototype can be designed, built, and installed in a test-bed mine for evaluation in a relatively short period of time.

Slides 18, 19, 20, 21, 22, and 23 touch on Dr. Chuck Jorgensen's work at NASA to develop improved communications through converting thoughts to digital signals. Now, this holds great promise for those who must work underground, and we are asking the panel to contact Dr. Jorgensen to learn more about his exciting new technology.

Slides 24 and 25 introduce potential equipment to allow seeing through smoke. And we're told the chances of successful escape would be greatly improved if it were possible to both see through smoke and breathe for at least an hour.

During the war in Vietnam a new technology was developed and has been improved since that time called FLIR.

That stands for forward-looking infrared. Now, here at ASI we think we can make that small enough to fit inside the face piece, as shown there, with a compass aid in escaping those hazardous situations.

Slide 26 discusses new technologies for locating personnel underground.

Slide 27 suggests that we invoke a non-traditional training method to deliver the all-important training that's associated with the process and safety.

Slide 28, ladies and gentleman, this is a quote 500 years old showing the difficulty involved in invoking enthusiasm for change. "If you try something new, there will be many aginners." But as Larry the table guy says, we need to get her done.

And with slide 29, we thank you very much for allowing us to present this. And as I said, this is a very, very brief overview of these items. And you can access these slides on the MSHA website, and get in touch with Bud either by email or telephone in a couple of days, and he would be glad to talk with you more about these items.

So now we hope we've kept you right back on your schedule. And we thank you for this opportunity.

MR. KRAVITZ: Okay, well, thank you, Janet. And tell Bud that we hope he feels better. And maybe we'll get to see him in person.

MS. MEYER: Thank you. He'd like that.

MR. KRAVITZ: Okay. Thank you very much.

(Applause.)

MR. KRAVITZ: What attracted me about that concept was it really brings together a systems approach. And basically, he's the only one who wrote to us talking about the whole system of actually escape through smoke using new technology. And there's a lot to gain from looking at what he has to offer. So his forte is actually bringing people together to get jobs done.

Okay. The last speaker in this session is Kelvin Wu. Kelvin is known to many of us. He's the Dam Safety Officer for DOL, Acting Chief for the Pittsburgh Safety and Health Technology Center for Mine Safety and Health Administration in Pittsburgh. He received his MS and PhD Degrees in Mining Engineering from the University of Wisconsin. He's a registered professional engineer and land surveyor in Pennsylvania.

Dr. Wu has taught as an adjunct professor in the Mining Engineering Department at the University of Pittsburgh, and he's currently teaching as an adjunct professor at WDU. He has served SME as Chair and member of the board of directors in Pittsburgh section, has been a Coal Division representative on the Book Publishing Committee.

He is currently a member of the Construction Materials Aggregates Committee, a program chair for SME 2007, a member-at-large for the Professional Registration Committee, a member of the Coal and Energy Division Award Committees, Mining Engineering Committee, Program Committee for Surface Mining, and a member of the Health and Safety Committee. A mouthful.

He has worked extensively in both coal and metal/nonmetal in the areas of tailings, dam safety, geotechnical engineering, involving high wall, open-pit stability, mining adjacent to underwater bodies, bulkheads, all roads and structure safety.

Please welcome Kelvin Wu.

(Applause.)

MR. WU: Thank you, Jeff. Good afternoon, ladies and gentlemen. I lost my voice somehow a little bit since last week. Just gradually getting it back, so my voice is broke up.

The last one for this panel is very difficult. Low tech all being finished. High tech we don't understand. So it's a little bit difficult, but I'll try. Take a different approach on the problem.

This particular presentation, what we're trying to brainstorm what we can do, based on the assurance we have through different incidents. And though I have Mr. Mark

Skiles, Director, and Richard Allwes and Terry Taylor in the audience, and they all try to get our thoughts together to put this presentation, so the comments are conceptual.

Now, we say, as all the previous speakers pointed out, if there's incidents happen underground, no matter it's coal or metal, if you can get out the best way, the safest way is just exit, get out safely. That's the first thing you do. Don't even think about stay down there.

Now, so this morning's presentation on the communication, training, and escape plans, all those things, lifelines, all most important. Get the people out of the mine. If there's a fire, you try to fight the fire. If out of control, get out. If you're going to have explosion, you didn't get hurt bad enough you can get out, get out. And there's flooding, like Quecreek's incident, actually 1980 the Jefferson Island incidents -- how many in audience remember Jefferson Island? Still a lot of people. Jeff, you were there, you didn't raise your hand.

Now, all those incidents, the Jefferson Island and the Quecreek, only the problem is when people -- Jefferson Island incidents, everybody exited safely, 57 miners. Quecreek unfortunately trapped, but fortunately enough, they all safe.

Now, the training is so important. And when I talk to the students, I say, well, regulations. Regulations apply both on coal and metal on escape routes. People walk out of emergency escape, that's the most try thing to do, perhaps most important thing to do. To familiarize yourself how to get out. So all I try to emphasize is, if anything happens underground, we get out.

This panel, we're talking about refuge chambers, refuge bay, whatever the term we use; that's a last resort. That's only when you cannot get out, and there's something there for added safety, and give some chances.

So we thought we use 1500 feet, but at a distance it's not really that important. I was trying to last, at a meeting, annual meeting, Professor Andrzej Wala of the University of Kentucky, he present paper to publish as a model study for the fire and the smoke promulgations. And those are the research work he done, can be utilized for this type of work, for future development.

We said in here that the distance based on the low-zero visibilities, the 50-percent supply, that's only for the 60 minutes, that's CSR, as other speakers stated, entry heights, all the other things, he's going to have a problem with the people walking out. Now, the distance they travel under the high stress. If he's in a coal mine, the coal seam is lower than five feet, you're going to reduce more, as far as travel concern.

So we set up with those things, and we said, well, provide a minimum, you know, thoughts, 72 hours supplies, if you get trapped. Once you get trapped, it's 72 hours. Well, like this morning's presentation by John Radomsky on the Mexico incidents, that's another couple months. And the things, we thought it was 72 hours, it probably is something a minimum, based on the other incidents.

Now, when we think about this thing here, we are not only talking about it only by explosion, we're also thinking about water, the inundation problems. And the accident cuts through. This is happening. It's the same, getting more and more. The things like Quecreek, hope that's the last one, most likely it probably won't be.

So if you're doing this refuge chamber thing, we'll also want to design, thinking about taking that into consideration, can hold it for high water pressures.

So we look on three different type, the possible refuge chambers, permanent, temporary, and portable. When we talk about permanent ones, I was very glad, many speaker by now on the panels, I personally had no contact before, and so we didn't collaborate or anything. The talk, the thought was along the same line.

This is just based on the research in talking about under different conditions, and how the individual can travel. And that SCSR, how much they can supply.

Now, permanent chamber. We suggest the permanent chamber. And Randy, you put in first. So I'll beat you on that one. You're installing the main travelway and escapeways. Permanent bore hole would be provided. We're talking about that's another thing. If it's a permanent one with one bore hole in the chamber.

There's two reasons, a couple reasons. Pressure is number one. Most speakers were talking about, based on experience they were talking about some of the cases. And there's other important things, if we can keep it in the positive pressures. We know we build bulkhead, no matter how we build it, it's not going to be able to seal. You've got high pressure, high positive pressure. We can keep the toxic gas out from the bulkheads. So keep that area safe and continual fresh air. That is probably most important ones.

Now we can continue to supply air supply and communications. Natural air is going to be a problem for the companies. If you're going to drill the holes, we know that. You've got to get surface rights, state regulation requirements. You know, you can keep the hole open or not. There's a lot of other things that we're not discussing here. What you're talking about is a conceptual thing we're thinking about, how to deal with this problem.

Now, there's one more thing is more important on the survey portion. Survey portion. Now, I'm going to go for the next one, the temporary chamber. The temporary chamber is going to put it close to the working area, with our thought is in active mining areas. But that will be no bore holes. You only provide oxygen tank, whatever needed in there. Now you can put air lines in, all those things. But we thought well, if there is an incident, explosion, chances are that air lines, water line, all those are going to get cut off. And we got to have independent supplies. That is our thoughts.

But I say the survey was extremely important for temporary ones. If we put temporary ones in the mine, that location has to be very accurately surveyed. The reason Quecreek is best example, all the things talking about it is that surveyor used the GPS system, while always contributed the credits to the underground survey crew. They did the best survey, and provided the points, the longitude, the latitude. And so on the surface he used GPS, anybody can locate that points.

So we know if it's temporary, if something happens, people in that refuge chamber, we know, as the other speaker talking about it knew, the drilling equipment, everything is so advanced, we can have high-speed drilling. We can drill into that chamber and provide fresh air. But if the location surveyor was not accurate, we're not going to be able to do it. So that survey becomes an extremely

important thing, the accuracy.

The third time we're talking about is the portable chambers; that is, removable. And the most we got some picture later to show on the market, where the most of them are not fire explosion-proof. And, Randy, your test is fire explosion-proof. On the market, most of them found it was not.

So this concept we're talking about it being a room and pillar operation. Say, well, we'll cut right into the pillars, into established chambers. Now, here I want to talk about, he tried to work with, you got the wall and the use of his knowledge on the model study to determine what's the best place to place those temporary chambers and the permanent chambers. And Professor Andrzej Wala was very interested to do this, so maybe more things can be developed in the future to utilize his model.

Light support system in the chamber which are required to be in there, to be furnished. Not much difference was with other speakers. Bore holes is the permanent ones. And the other things we needed.

Now, we're talking about a requirement on the regulation at the present time, and CFR 75.1500 do have coal refuge chambers requirements. And some of those provisions is quite in detail, quite in detail. It's not mandated, but if you do put a refuge chamber, there's a requirement.

Metal/nonmetal, 57.1105(2). Joy, is that correct one? They require the provisions you have to have. Compressor air line issues gives different type of problems. This is two incidents occurred in Ontario, Manitoba. They had problems.

Permanent chamber, we're talking about. That was interesting because, Randy, you're talking about double bulkheads, we're talking about double bulkheads. And, Randy, we never met before, right? We never talked about it.

MR. BERRY: It's all been a set-up.

MR. WU: I thought it was the same thought process. So is the locator large enough to accommodate all the miner in the areas.

Now, we say the designs should resist minimum 80 psi over-pressure. And Mr. Richard Elms joined us recently; he's from Army Corps of Engineers. So they have some other thoughts. So that's adding things to our work.

And last week I saw on the Discovery Channels about hurricanes, and the University of Texas. And they shoot these air guns, shoot these two-by-four stud in the hurricane. Anybody saw that segments? On the brick walls, they shoot right through it.

What we're talking about is, the projectors, when you have an explosion, in the abandoned area you have a lot of debris. When those things being through at a high velocities, there's a lot of other things could happen.

Inundation hazards. Now we said well, this bulkhead has the design it can hold minimum 100-foot water. And that won't be a surprise, because we have so many mines right now being abandoned, and those was flooded. Most of those mines are flooded.

Now, when mining adjacent mines, adjacent properties, that that risk always exists.

Now, we say this bulkhead has to be able to survive initial and secondary explosions. God forbid you never have a secondary explosion. But we know experience tells us it happens.

The concrete design for explosion as a certain requirement, different type of concrete for water invasion to coal. Foundation investigations. I was glad to hear Randy talking about prepared foundations. That is extremely important elements.

How to anchor into the stratus. Whether we need a grout curtain or not. Those are things that's in the thinking process, do we need them for the bulkhead design. That we have them evolving mining industry, doing a lot on bulkhead designs, to separate mines.

We're going to do this to try to reduce permeabilities. We say on both sides the bulkheads should be supported, supplement support, to reduce chances for the convergence on the bulkhead. So reduce the bulkhead subject to the high stress. Other supplementary roof support should be provided.

Under the doors. It has to be airtight doors, explosion-proof. So we're looking through what is available on the market. Fire rate, that has to be looked at. Rock anchor, that has to be taken care of.

We need a construction plan and specifications. We need a design first, then we need a construction plan and specifications, material specifications. This seems so serious, you better make sure, we better make sure the material is what your design plan calls for.

And the most important we thought, those things has to be certified, that type of structure has to be certified. All the material testing during the construction has to be applicable to ASTM standards. Inspection by the contractors, all MSHA personnel whenever it's available, when it's very doubtful they can do that. It should be the mining industry's responsibility in this part, because that's a daily operation, so it should be checked so frequently, particularly during the construction period, for quality control.

You can spend a lot of money to design, and by the end of the construction did not build a quality design plan, and everything is of no use basically.

Now, this is just talking about all the different designs in our mine, what we thought, and it can be done. You have this bulkhead with tight door, with bore hole predrilled, predrilled. As you can see, the bulkhead, and this is three-foot doors, this is the temporary ones, temporary ones without bore holes. But as I mentioned, we needed the survey of this location extremely careful, be accurate. So if incidents happens, the people is in here. Whatever method we're going to have to find the people is in this chamber. We know the location, and we can do the high-speed drilling, we can reach them in very short time.

This is not just different ways we're thinking of steel layout, how we're going to construct this bulkhead. This is on the market. This is the ones they're using on the offshore drilling platform, or shipping industry use for the high-pressure doors. And those doors are reusable. So they use this, you know, when the area section is abandoned, those should be retreated, and for the next location it's for reuse. Those are quite expensive. Those can hold for high water pressure.

The following just all different picture which show what the person time in the mine, you know, has been done. Has been done in contact grouting. This is the ones in Canada. As you can see, because it is potash mine, at a fire where there's no explosion, the fire is far away. It cannot be close. If it close, all those corridors would not going to be closed.

Now, for their purpose, it didn't serve adequately. Portable ones. We thought the portables would be mentioned because in underground conditions, if I have isolated area for certain construction crews and doing work in separate main areas, maybe portable ones would be suitable for them in case for any unforeseeable events.

Through a search on the market, find a different type portable chambers. But would you believe all those is not fire explosion-proof. But they have all the specification capacities and all the detail in their brochure, so I just very quickly went through those. Those are available on the market today, even the portable ones.

So that's basically quickly the brief, gives the thoughts, what we're thinking about, the concepts. Things can be done. There's a lot of work still need to be done. And hopefully that can serve the purpose of what we're talking about today, to save lives.

Thanks.

(Applause.)

MR. KRAVITZ: Okay, let's take a 15-minute break. We'll be back about 2:25.

(Whereupon, a short recess was taken.)

MR. FINFINGER: Okay, I'd like to start the presentation forward. We'll be getting presentation from various manufacturers, and they'll be talking about what is currently available in the market in terms of this topic we're covering today.

The first presentation will be given by Ed Roscioli from ChemBio Shelter. Ed is the CEO of ChemBio Shelter of Allentown, PA. Over the last three years he designed and produced emergency shelters for use by the U.S. military to protect troops from chemical and biological warfare agents. In designing chemical bio-shelter, Roscioli applied principles learned during 30 years of work at nuclear power plants.

The shelter generates pure oxygen from a solid chemical, and scrubs carbon dioxide and carbon monoxide from the atmosphere.

Yes, Ed, are you here? And by the way, these presentations are 10 minutes each. Please try to stick to that time.

MR. ROSCIOLI: Thank you, Gunnar.

As Gunnar mentioned, I was in the nuclear power industry for about 30 years, and I worked at a lot of the different power plants in the United States. That just means that I lived in some godawful places.

It turns out one of them, I remember distinctly, was Edwin I. Hatch Plant near Vidalia, Georgia. And I was going down there for the first time, I'd never been there before. And I asked one of my colleagues, because he had been there for a couple years at a previous assignment. I said, what's it like down there in southern Georgia?

And he says, well, let me put it to you this way. If my doctor told me I had six months to live, I'd go live in Vidalia, Georgia. I said whoa, it must be really nice there. He said, well, I don't known if I'd call it nice, but that six months would seem like 20 years.

(Laughter.)

MR. ROSCIOLI: The tragedies and Sago and Alma in January of this year jolted us, and awakened us to the dangers that miners face every day. We share the grief the families of the victims have, and we extend our sympathies to them.

Now let's share our collective wisdom, and extend the solution to all the miners that take these risks to provide these resources to us.

I've worked, for the past three and a half years, on a ChemBio Shelter. Really it was designed in concert with the U.S. military to protect the war fighter from chemical and biological warfare agents. And this particular shelter, you can actually keep someone hermetically sealed in it for extended periods of time: four days, seven days, 10 days, if you have enough of the chemicals.

If we had anticipated the usefulness of this shelter prior to January 2, we're confident that we could have prevented these tragedies. We could have given them air, food, water for 96 hours or more. And that was enough time for them to be rescued.

That's why we're working diligently and continuously to provide the most reliable, economic, and technologically advanced way of providing a safe haven for these trapped miners.

An essential part of our overall strategy was to partner with an experienced, well-respected emergency shelter manufacturer. Zumro is that manufacturer. They've been supplying shelters to emergency service personnel for more than 18 years now, and they stand out in the industry for rugged durability, design flexibility. And they use a low-pressure air beam construction, and that allows it to be rapidly deployed. And you'll see a little later in the slide show, we have an actual video embedded in there of one of our shelters being deployed.

We take pride in having been selected by the Department of Defense to take part in an $8 million testing program. And this was to find viable methods and systems for protecting the military from chemical, biological, and radiological warfare agents. This testing was done by the

Joint Program Executive Office for Chemical and Biological Defense just this past December.

There was a five-day extensive test, and during that test they actually subjected our shelter to a chemical warfare agent simulant. And our shelter did not allow any of that simulant to go through its wall. And they had absorbent tubes inside to monitor it for the entire duration of the test, and they had no detectable indication of any chemical inside the shelter.

As part of the testing program, they also checked out our decontamination unit and the air lock and mortar lock for providing transition between the decontamination unit and our toxic-free area, which is the hermetically-sealed shelter.

On February 8 of this year, we had the opportunity to demonstrate the shelter to a group of industry regulators and mining executives at the experimental coal mine in Bruceton, Pennsylvania. We got strong praise from that, and we also received some insightful comments. We took these comments seriously, and we made some engineering changes that have made the system even more suitable for the mining industry.

Today we feel confident that we have the best solution for giving trapped miners a safe haven where they can survive until help arrives.

As we can see from the comments and discussions this morning, a mine rescue shelter meets a critical need. It provides a safe haven for miners that cannot escape. It assures that they have a safe haven with a life-sustaining supply of air when, where, and for how long they need it.

In the event of an emergency situation -- for example, an explosion, fire, flaps, poisonous gas -- the first line of defense is always to exit the mine. And there needs to be a concise escape decision-making process. The last thing we want or need is to have miners staying in the mine that could have safely escaped.

But we also do not want miners making panicked attempts to escape that lead to disastrous results when it is not safe, or impossible to exit the mine, these attempts that could be prompted by the belief that barricading will lead to certain death. The availability of a viable safe haven, a rescue shelter, gives them another reasonable option. It removes that sense of panic, and helps give them presence of mind to make the right decision.

It can also do a few other things. It can give them a place to rest, collect their thoughts, treat their injuries, and then move to evacuate or wait for help. Also, it gives them a known location, a place where the rescue teams can focus their efforts.

As I mentioned, there's a rapid deployment due to the air beams. We're going to see the video now. It's about a 43-second video of our shelter that's being deployed at the MSHA Academy in Beckley, West Virginia just four weeks ago today.

(Video played.)

MR. ROSCIOLI: Okay. Notice when that shelter was deploying, no one had to touch it. You just open an air valve, and it automatically sets itself up.

This is part of our ease of operation. To deploy the unit, you just open the panel, and pull the door release. You open the first valve, and that deploys and fills the shelter with fresh, clean air. Then you open the second valve, and that lifts the shelter to the available height of the mine seam automatically. The door release and the valves are clearly marked, they are color-coded, and they are ordered from right to left, just like we read.

Once deployed, the miners simply enter the shelter through the air lock. Then once inside, they start the air-processing system, which maintains the breathable air supply by generating oxygen, removing carbon dioxide, carbon monoxide, and other pollutants from the air.

The durability of this system, it's a rugged and durable shelter material, and it's built to withstand the mine environment. It can withstand dust, falling debris, humidity, and it also can withstand multiple deployment, redeployment within the mine to ensure that it is ready and available when needed.

As previously mentioned, the ChemBio Shelter was designed and developed to meet the demanding military standards for protecting combat troops from the life-threatening effects of chemical and biological warfare agents. It has undergone extensive testing by the U.S. Department of Defense.

This revolutionary and ruggedly-constructed shelter provides an impermeable barrier from the life-threatening atmosphere created by high concentrations of carbon monoxide and other toxic gases. It is flame-retardant. It meets UL 94-V0, which is the highest level of flame retardancy that Underwriters Lab has. It is puncture- and tear-resistant. I have some samples of the material. If you see me afterwards, you can try to rip it. And unless you're extremely strong, I don't think you're going to be able to.

And unlike some of the other concepts on the market, our shelter is available now. We have production capacity that we can quickly gear up to meet the need. We have plants in place, and we have equipment and inventory in store right now.

This is a quick, just a diagram of the shelter itself. It's attached directly to the heavy-duty cart that it comes in. Again, the duration and the other issues such as power, we don't need power to run this system. Absolutely totally power-free. The only power in the whole system are little lithium batteries in the detectors that last two years, and they are intrinsically safe. There is absolutely no other power to run this whole system.

The shelf life you see is in terms of years. It's air being deployed. These are the detectors. We have one for carbon monoxide, carbon dioxide, and oxygen, and they can measure the air both inside the shelter and outside the shelter while the people are still inside.

So in summary, the long-term air supply we can provide, 96 hours or even longer. It's mobile, because it's on a skid-mounted cart, so they can move it along. And the cart is only 20 inches high, for those low coal mines. It can be rapidly deployed, and it has absolutely no power requirements. And it's available now.

Thank you.

(Applause.)

MR. FINFINGER: Okay. I think reading CVs are included in the 10 minutes. Somebody gave me a CV three pages long. That person needs to make a choice. Either I read the whole CV, or --

(Laughter.)

MR. FINFINGER: -- the whole presentation.

Okay, the next speaker is Mr. David Baines from the O.C. Lugo Company.

VOICE: Excuse me. I asked Mr. Kravitz for time. I wanted to address a comment that was made in the last panel.

MR. KRAVITZ: We're going to get at the end --

VOICE: Jeff, this is very important. It casts very bad light on our company, and some people here are on very thin ice by making statements that they have made.

MR. KRAVITZ: Well, you'll get a chance to correct it at the end, after the last panel.

VOICE: All of these people, this is a science academy, Jeff. We come here for truth. We come here because we want to hear the facts of material that is being presented.

Whenever somebody makes a statement that over 100 people died because they couldn't get our chambers opened, that is not true. It never happened. And what we want to know is the source of the information, what mine it happened, and when.

MR. FINFINGER: Look, I'd like to suggest we handle this issue in the question-and-answer session at the end of the day.

VOICE: That would be fine. I just want all of you to know that it did not happen. If 100 people died, we as the manufacturer would certainly be notified. We have never been notified of 100 deaths because our unit was not able to be opened.

Mr. Oberholzer, I don't know if he is still here, but I would definitely like to know what mine it happened at, and when.

MR. FINFINGER: Okay, we'll continue our discussion right at the end. It's good to have good questions like this, it keeps us awake.

All right, let's continue. The next presentation is from David Baines. He is Sales and Marketing Director of Molecular Products, Ltd. in UK, a supplier of CO2-absorbent materials, chemical oxygen generators, and filter media for confined space and collective protection.

David has over 20 years' experience in sales and marketing of industrial products to the chemical, pharmaceutical, petrochemical, industrial suppliers of instrumentation equipment which are used in safety emissions monitoring, patient protection, and process control.

MR. BAINES: Good afternoon, ladies and gentlemen. Why am I here? Well, this is one of the reasons why I'm here. The company, Molecular Products, provides a number of technologies that are used in confined spaces. And an example of that confined space would, of course, be a military submarine.

The company has three capabilities that I want to talk to you today about, and then apply them to your application within the mine industry. The first of those is it makes gas filtration products, such as CO absorber, H2S scrubbing materials, and other materials that absorb CO2 in the military application that I've just talked about. There are, of course, applications in industry and environment, as well, for those filtration products.

The second capability is the production of chemically-generated oxygen. Whether this is used in the confined space of a military submarine, or whether it's in the health care industry in the form of a portable can of oxygen that is provided for emergency patient care. And indeed, in confined spaces we have an instrument that I'm going to talk to you more about as well later.

The company manufactures CO2 removal devices, many of these being used in breathing circuits in medical applications, but also in military diving sets, and indeed in breathing sets which are used in parts of rescue operations as parts of mining applications.

So those are the three capabilities that I wanted to talk to you about.

The company has identified that the combination of these technologies can be used in mine refuges and safe havens, and indeed in civilian bunkers or safe havens, as well.

Our customers tend to be shelter designers and builders, and indeed, shelter operators. So we are able, then, to combine the chemical oxygen generation with CO_2 removal in such environments as you've been discussing this afternoon in those shelters. It is an independent supply of oxygen that we're providing, so it is not relying on compressed air being supplied. It is capable of supplying over-pressure within the confined envelope that is defined. And it also scrubs out the carbon dioxide which is exhaled from the inhabitants of the confined space. And of course, it is the CO_2 that gets you first, not the lack of oxygen.

So we've taken these technologies, and put them into a portable atmosphere control unit so it can be used in a confined space, or safe haven. This unit here is going to be able to monitor its environment using electrochemical and infrared sensors. It scrubs the atmosphere for a defined number of people; in this case, the unit has been defined for four people for 24 hours, in a 32-meter-cube environment. But in fact, it can be scaled up to be used in any defined space, it just has to be specified.

The unit that's crawling through behind us is built up of a CO_2 absorber unit, which is on the base of the instrument. It is there with its own self-powered unit capable of functioning for 24 hours non-stop, scrubbing out the environment in the defined space that I've used for this example. Indeed, multiple CO2 scrubbers can be stacked one on top of the other to provide increased capacity for larger defined environments. And the period of 12 hours doesn't limit the instrument, because you can exchange these units. They're consumable units, so you would have a store of them sufficient for the defined period of time you wish to sustain people.

You also, in the unit, then provide a self-contained oxygen-generation unit which sits at the top of the device. The fan system drawing the air from the environment through the CO2 scrubber then passes by the self-contained oxygen-generation devices, which will produce, according to the oxygen level environment, further oxygen to maintain a 21-percent oxygen environment within the defined space. These are automatically controlled, and can be fired off by the machine themselves to provide that 21-percent oxygen atmosphere. And it also enables you to exchange these units and put in consumable supplies for the defined period that you set out to maintain the people for.

It also has an oxygen readout system, and monitors the CO2 automatically, and displays that on the unit. And as you can see, it's a fairly compact unit in its own right.

(Applause.)

MR. FINFINGER: He saved us seven minutes. And a short CV. Well done.

Okay. The next presentation will be given by Mr. Ian Houlison from Phoenix First Response. Ian started in mining in 1975. He worked at the various places. He has experience from Australia and United States. He worked at New South Wales Mine Rescue Services, Queensland Mine Rescue Services, Phoenix First Response as a Manager in Glassport. And in 2004 he was appointed as Safety Director.

He's certified as mine rescue instructor and operator, police rescue operator, ambulance officer. As I read this through, I feel myself very safe here.

(Laughter.)

MR. FINFINGER: And Ian has been a presenter for various papers on mine rescue and mine inertization throughout Australia and U.S. Ian.

MR. HOULISON: Thank you for that sterling introduction.

Phoenix First Response and Mine Emergency Shelters and Chambers came as a result of a lot of effort, through a lot of people. Essentially, it was driven predominantly by underground emergencies. And each individual human being has that essence, being the flight-or-fight response, what do I do.

I'm trying to put you in an emergency situation of where you're sitting, where a fire has broken out, an explosion has occurred, or whatever. And your first thought is what do I do. So the non-trained person, his reaction is, who can help me. Who is around who is going to be able to help me?

Previous speakers have identified the fact that we need to have a leader that comes forward. A trained response, timely and rapid intervention, will give us the early resolve, so that people can be retrieved from within the coal mine fairly rapidly.

Egress from the mine are the primary or secondary escape routes. Which one is available to me? Which is the best for me to escape through? Or do I stay underground for rescue or retrieval? What's the best possible protection? And this process becomes involved, because as you go to the next level, then these same questions start to arise.

In emergencies, it generally can be divided into three areas: self-escape, which is predominantly the best way of getting out of the mine, where people don their self-rescuer and escape with little or no injury and exiting the mine with the potential use of SCSRs if it's required.

The aided escape is often overlooked. An aided escape really is about mine workers who are injured or may be assisted by fellow workers exiting the mine, or retreating to a place of safety. Those people who are retreating to that place of safety, or your rescue chamber or rescue bay, or whatever you choose to call it, can then be retrieved from underground by rescue teams.

The mine's rescue philosophy then comes about by the historical involvement of the entry into the affected mine by trained personnel wearing appropriate devices to retrieve injured or trapped mine workers. This may also involve retrieval from that place of safety, as I said earlier. And that place of safety will afford protection to the mine worker.

So we'll go back into this with the fight-or-flight response. It's a danger. It's a human interaction to defend life or to escape danger.

This inherited reaction is involuntary, and as such, requires harnessing in an underground emergency; i.e., training. People have to be trained to overcome that reaction of fight or flight. Trained personnel are taught to SLAM, or to stop, to look, to assess, and to manage their environment.

Underground emergencies demand all trained skills to come together in often hazardous environments. So people in an emergency have this resolve. Step one is to stop. Say not so fast, I can look around and think about what's happening. Think through this emergency. Is this life-threatening? Has the gases present been determined? Do you need SCSRs now, or do you need them later? Can I communicate to the surface? Which is the available best escape route?

The step two is to identify the hazards of each reaction in the emergency, and this step begins before any immediate reactive response occurs. To determine the essential steps to maintain life and property, address the issue of identifying noxious or poisonous gases and identify hazards for SCSRs. Check all communication links to the surface, and identify any escape routes that exist under the present condition.

Step three, analyzation or determine if you have the knowledge, training, and tools required for the job to identify key people within your group. Experience helps to identify potential hazards, obviously. Assessment should continue throughout this active response to the incident. Share the identified hazards with others in your group. And remember, two heads are better than one when you go to this situation.

Step four is to manage or to remove or to control these hazards, and the use of appropriate equipment. Utilize established control methods. Eliminate or remove the hazard completely. In other words, if you can't get out of the coal mine, and you have a place of safety to go to, go to that place of safety.

Substitute. Reventilate from a fresh air source.

Engineer. Enter an established refuge chamber and wait it out. Sit it out if you have to. Administrative, follow the written response instructions on the personal protective equipment such as SCSRs.

The training side of it, mine officials receive training in their years of study, but they never need to use the knowledge. The fall-back then becomes the SLAM philosophy. If you haven't used the knowledge, then you need to have this fall-back. Mines rescue personnel receive training and practice in emergency response, and utilize this knowledge on a regular basis to instill this skill indelibly. People that are trained this way will take the lead, and will often lead people to safety.

Mine workers rarely receive practice in emergency response, but will have the knowledge base through the annual refresher training obligations under MSHA. This will give them at least a little base, at least somewhere to come from, and the mines rescue people will tend to lead from that point onwards.

So the response situation is the basic mines rescue principle is to provide timely, rapid intervention to emergency events that impact the United States mining industry. The fundamental principle has its roots in history, where this concept of rescue chambers began. This took the form of teaching the concept of barricading to mine workers awaiting rescue in small mines. This is very dissimilar to the larger mines of today.

Simply put, mines rescue relies on the physical strength of the trained man to effect a rescue and recover individuals from a hostile environment, some of which may need to be carried. The egress from the mine, from a refuge chamber or place of safety, the endangered miner can be either provided with an agreed safe route of egress from the mine with available communication systems.

He can also retrieve additional SCSR escape devices, or replenish deployed self-rescuers nearing the end of their life. They can retrieve stored mine plans to permit an ease of identifying egress routes, either primary or secondary, whichever is the safest travel at that time. Be supplied with information from the surface to aid the escape from a hostile environment, and/or remain in relative safety.

The Phoenix Chamber then. Mines with those established refuge chambers afford greater protection for all people underground. Mines can now also utilize this place of safety as a major communication link to the surface, and give their mine worker a safe haven to sit it out if this is the required course of action. Mines, in an emergency response mode, now have time to plan the rescue and recovery effort that is not time-critical, as those mines don't have rescue chambers. It gives us time. It gives us time that we can look at how we're going to retrieve these people underground.

So we come to the essential criterias of the refuge chamber. And the Phoenix refuge chamber basically comes to the forefront here. We're thinking of entering the rescue chamber so that we have, I guess, an air lock that goes between the people when they're in a safe haven to entry where rescue teams can come in, or extra people can enter that refuge chamber.

We looked at the fact that they also need to have some facilities in there, such as toiletry facilities and the like. Air supply will give us a means of maintaining life. This chamber that's identified here basically is probably the one that's going to be closest to the face area that's a portable unit.

And if we have this portable unit in place, it will afford us some protection that will give us some time for people to either retreat to a place of safety, or be rescued from that place of safety.

You can also see that we've got the storage areas for the blankets, the pillows, the first aid equipment. All of that sort of things are all accommodated within the chamber.

The Phoenix Chamber, the out-by door will open out to resist an over-pressure. The in-by door will also open out to give an air-lock arrangement. All corners braced for over-pressure resistance, according to RPE that endorses this. The bench seat is to be designed as a storage area for additional supplies, like SCSRs. Blankets, first aid supplies, EMT kits, or for definitive care of patient, oxygen therapy units, et cetera.

Internal wall is filled with foam for insulation and comfort, and the interlock entry door is to guarantee this air lock arrangement.

That's about all I have to give. I thank you for the time that you've given me here. And I believe strongly that this mining industry does need these sort of places to afford protection for our mine workers. It's critical to afford this protection to these people. Thank you.

(Applause.)

MR. FINFINGER: Okay, we're making good progress. Our next speaker is Mr. Rohan Fernando. Rohan's position, he's the Manager for Breathing Gas Systems. He works for Draeger Safety Systems. He gives me a description of what they do, but I'm sure we'll hear about that during his presentation. Rohan.

MR. FERNANDO: Good afternoon. Thank you very much for inviting me to give this presentation here.

I'd like to give you an overview of Draeger's shelters that have been designed and delivered to various countries mainly in Europe.

Draeger's experience in designing shelters and shelter systems is drawn through delivering these systems and solutions to the industry and to the government. Some of these systems are used in off-shore platforms, rescue trains or railway vehicles, and also for mining and tunneling.

These are some examples of custom shelters. For example, these in a tunnel. And that particular design was a solution to actually conform to the shape of it. You can see here gas supply cylinder banks, and access to this shelter was from the front here. Or from a tunnel viewpoint it's from the side.

These are the shelters. And again you can see some of the dimensions tailored to fit into that particular application.

More examples. These are interesting design in that the dual wall is set at an oblique angle in order to take in a stretcher without tilting it too much. Sometimes our shelters are designed based on standardized shipping containers, and modified in order to achieve the protection and the function that you need from these.

The protection principle, we've heard a lot about the life support system that goes into shelters in a lot of the previous presentations. These shelters designed by Draeger are for protection to users by creating a respirable atmosphere inside an enclosed space. This protection is ensured by maintaining the oxygen level in the range 19 to 22 volume-percent, maintaining the carbon dioxide level to less than one volume-percent, and creating an over-pressure atmosphere inside the shelter.

In addition to that, we are also looking to cooling. And a lot of these shelters are made with the air conditioning systems. Here is a graphical impression of that system here. A scrubbing system is used to control the CO_2 levels. The air supply from fixed to hypercylinders is used to create an over-pressure, and oxygen from oxygen banks or cylinders is used to feed in the oxygen to make up oxygen that is consumed by the occupants.

In certain cases, we also install the systems outside the shelters. That depends on the customer's preferences. And some of the general features of these shelters are, once again, see the CO_2 scrubber in this case in an outside unit, O_2 supply, a couple of cylinders over here. The breathing air supply in this case in cascades, cascade banks. Air conditioning, you can see that over there. Alarms and sirens and over-pressure valves basically to control the over-pressure, or to maintain the over-pressure in the shelter.

Gas-tight doors are necessary, as you've heard also in the previous presentations, to maintain the fresh air inside. And, okay, external air supply, delivery of power, battery power, and standard light.

This is an example of a CO2 scrubbing system installed inside the shelter. And it's normally installed underneath the bench. We have dual air conditioned twin blower system. The blowers are housed in this, at the ends of the unit. And it's, of course, designed for battery operation.

The flood line is contained in cartridges, and spare cartridges are stacked so that we could double the calculated time for the scrubber unit.

Now we are off the inside, I would go through every one of these, but the basic control elements are there. The air control, oxygen control, filtration of external air supply, battery control, and electrical switch gear. This also, now that we are off the gas-tight doors from the outside. Sorry, from the inside.

The other equipment of course are necessary, and in this case you can see a toilet, maps of emergency evacuation routes, food and water, first-aid equipment, and additional breathing devices, portable gas monitors can all be stored over here.

I'll go back a slide here to show you that is basically our portable gas monitor. That would measure your O_2 and CO_2 on the inside. Now, of course we can also monitor the gases outside.

So, in summary, shelters can be designed to a required specification, according to site conditions. And these would be smaller shelters for low seam heights, shelters on skids or wheels for transportability, inflatable shelters or assembled shelters, or even stand-alone life support system for built-in shelters.

In this case, these are life-support systems, for example, for 10 persons for 12 hours. And basically, it consists of all the elements. These are the same elements we talk about all the time: the oxygen, the air banks, and the CO_2 scrubber, and also cooling.

Now, modifications necessary to current designs will be driven by MSHA and mining industry recommendations. And we at Draeger basically are here for that purpose, to learn from the authorities, as well as the industry, of what is required from these shelters.

Some of the things that come to mind especially of coal mines would be MSHA-approved components and parts, intrinsically safe electrical equipment, maybe even explosion-proof, fire-resistant material and insulation, training programs, and other modifications.

So with that, I thank you for your attention.

(Applause.)

MR. FINFINGER: I'd like to encourage you to give us your written questions. We have about 15, 20 so far. I noticed that the most serious and difficult questions are for Dr. Jan Oberholzer.

Okay. Our next presenter is Mr. Alan Becker, U.S. Navy. By the way, he's very well represented here today. He is from U.S. Naval Academy, graduated with MS in Ocean Engineering Degree from MIT. After serving in U.S. Navy as a diving engineer officer, he retired to work at PCCI. He has been involved in the design and production of life support systems for the last 20 years.

Mr. Alan Becker.

MR. BECKER: Good afternoon. I literally feel like a fish out of water. I have spent my entire adult life in, around, or under the water. But I did that learning life support systems. And if you think of what we're talking about right now, the mine shelter is a life support system.

I have worked with Cowan Manufacturing of Australia for about 10 years. Cowan has built the U.S. Navy's standard Navy double-lock recompression chamber. Again, not a lot different than a refuge chamber.

This unit that you see right here is in production and in use in Australian mines. I'm going to talk about this unit. At the end we'll discuss some of the modifications that we can do.

I'd also say that from my colleague from Draeger, me, too. Because everything he said is going to apply to the chamber that I'm showing you, so I'm not going to spend a lot of time on this.

Ours is a rigid-construction chamber. And here you see it in the low position. This is to accommodate those places where we have four- and five-foot tunnels that we have to get through. The roof is dropped down to five feet in this one. We have another one that drops down to four feet.

When we get on site, the roof is expanded up to its height of seven-foot-three, and it's about an eight-and-a-half-by-16-foot footprint. What this allows us is to be transported with the common machinery that you find in the mines today.

I'd like to take you on a quick guided tour into this unit. This is a 12-man unit. This is also a double-lock chamber unit. There's two compartments to it. That allows us to bring people in, and not lose the air that's already in there.

You're looking down towards the back end of the unit, and you can see the pistons that raise the roof and one of the CO2 scrubbers.

This presentation was put together by my Australian counterpart, and it's written in Australian. Freezer unit means environmental control unit. That's a heater or chiller unit. And that becomes important when you're on an oxygen candle, and you're generating heat. The oxygen candles are an exothermic reaction, and that compartment will get hot fast. So we have a unit in here which will control the temperature hot or cold.

Air. Air is supplied in three ways, just like all the others. You can either take outside mine air, or you can take compressed air from tanks, or you can recondition the chamber air. Gas is supplied. The air is supplied in the five bottles in the main compartment and two in the entry compartment. Oxygen is supplied in two bottles.

Here we see the filtration system for the outside air. Air from the outside comes in here, and we filter it. The air supply is also used to put a curtain between the entry lock and the main lock. This allows us to keep the pollutants from entering into the main chamber.

The system is under a positive pressure, so we have a relief valve and an external valve to keep the air inside, and not allow it to escape when we don't want it, yet allow it to relieve if we get too hot.

Oxygen supply. Again, this is an oxygen expansion tank. The oxygen comes into the tank from the flask that we have, and then is dispersed in doses to maintain the oxygen content at the 19th at 22 percent.

CO2 scrubbers. We have two of these scrubbers. They have soda lime in there. These happen to change color as they get used up. And when you see the color rise up to the top of that limit, you change out the canister.

Access. Here you can see the inner lock and the entry lock. The entry lock also has a chemical toilet and a wash basin.

The two scrubbers are powered by on-board batteries. They have a 24-hour capacity. That's not the limit. That's what this unit -- this unit is meant for 12 man-days, 12 men for one day, four men for three days, or some other mathematical permutations of that.

The canisters do require periodic change-out, and it's approximately every three hours with 12 men. Again, the system was designed for 240 volts AC, but that's just because of where it exists right now. It does have an internal power outlet where you can have a charger plus a spare. Everything operates on 12 volts DC.

Here you see the batteries. These are standard auto batteries. You can increase the size of the batteries or increase the number of batteries to extend the duration.

This is the part I'd like to really talk to you about, is the current designs. Right now we have a design that will take you to 90 man-days, nine men for 10 days. That number is not hard or fast. Remember, U.S. submarines stay under water until their food runs out. That's measured in months, not weeks or days or hours. So the limit is technically feasible. You have to decide how long you want this unit to endure.

We're evaluating alternative power units. Several things, including human power. And I think human power plays into some psychological issues that we'll talk about later. We need to have something to do.

The other thing is increase the pulse loading. I'm not convinced that these units cannot be explosion-loaded, or have a design for explosion-proof. I can design the chamber so that it withstands the pulse weight. The problem you have is that pulse weight is going to knock the chamber somewhere further down the tunnel. But there are ways of designing the location of that to allow you to absorb or deflect the explosion weight.

So the designs that you see, and you're going to hear some more about the same things again from other portable units, are there. The technology exists. You can buy this unit today. There's nothing magic about it. It uses proven technology. It has not met any MSHA standards, because I don't believe there are any standards as yet. So that's the issue that we're going to face is what standards we have, and what the qualification process is.

That's all I have, and I'll take questions at the end.

(Applause.)

MR. FINFINGER: Our next speaker is Mr. Dwayne Towery from Gamma Services. Dwayne is the Vice President of Gamma Services International, which provides the rescue POD proximity detection system called Tramguard, a miner tracker system, and a gamma detector used on continuous or high-wall miners.

Dwayne is a fourth-generation coal miner, with 12 years of mining experience in maintenance and production support. He also has an 18-year background in emergency medicine, which he currently works as a flight paramedic for an air evac life team.

He has a Bachelor of Science Degree, and he has also completed all the prerequisites for pre-medicine.

MR. TOWERY: Thank you. I'm sure everybody sat there and, here comes another one to the podium. So I'll make it short and sweet, and keep it as small as I can.

I just want to thank you for the opportunity for everybody coming out today. I know a lot of other things were going on.

The first thing I want to start with, why a rescue POD? Well, everybody knows since January that some of our colleagues have fallen. And with that, we have been looking at modern technology, trying to pursue with the mining community to prevent any more losses.

And a lot of people have talked about sealing brattices. And I know that the years and years I've been underground, that's something we always talk about in recurrent training. And that's just kind of a last-ditch effort. I mean, after your fingernails are bleeding where you've tried to climb over rock falls, that's where you go to. And I was underground Friday and Saturday this week, and talking with some people, and they have this same thought pattern on that.

And miners are among the most independent and self-reliant people in the world. You can give us a hammer and a screwdriver and a ball of tape, and we'll make some wizard thing up, and make it run or go somehow. It's just a coal miner. But naturally, miners prefer self-rescuers than to rely on a rescue party to reach them from the surface.

The first thing we've got to do is, everybody's talked about rescue PODs and all this equipment. You've got to build the trust in that miner's mind that it's going to be there when he needs it at the worst possible time.

Some of the key components of our rescue POD, it's a fully-deployed, rugged steel enclosure to help shelter miners from secondary explosions and possible roof falls.

We're going to go by the MSHA canopy standards for our roof on it, and provide a breathable oxygen.

A POD typically stays at the mining unit if you want to put one out by the working sections. But that seems to be where everybody is going to revert back to.

Our standard-size POD right now is, it will hold 16 people for 96 hours. It's 16 feet long. Ours is a short little fellow now; it's only 3.7 feet high, and less than six feet wide. In Kentucky where I'm at, we don't have any of these real tall coal mines, so everybody's bent over. And it's going to be kind of hard to get some components through.

We're also incorporating our through-the-earth battery-powered geosteering tracking system in or near the POD, so that way you can have two-way text communication with the individuals inside of it.

Some more key components. The mine atmosphere with as little as four-percent oxygen can be used as an oxygen source. In a fire situation that if you go and take the oxygen out of the air for the fire, then typically anybody that's been downstream, they've had a bad day. Well, we want to look at that a little bit different. Put a temperature-reduction support system in it, because, as everybody said today, you get enough people in there laying around, you're going to build some heat. So you've got to be able to get rid of that heat.

We're going to use a scrubber system, and our dehumidifier inside the rescue POD to get rid of some of the water and the CO and the CH4 that's outside. Portable self-contained breathing units add to the interior oxygen supply, and interior and exterior monitoring for the methane and the CO levels. And I'll go into that a little bit more in just a minute.

Well, ours is not the Taj Mahal, but at least we're going to put a little bit of water in there, and food and granola bars. We'll get them through for a few days if they didn't bring their lunch bucket inside. We're going to put a canister toilet in there; bodily functions still go on, and these men and women do have to use the restroom.

We're going to use some chemlight sticks, because they're small, and they'll give a little bit of light off. And as I said a minute ago, we're talking a little bit different here about firefighting. We're looking at nitrogen-foaming firefighting as a technique to put, if the people are downstream and you're upstream, and you're fighting the fire, you can actually fight the fire and push the nitrogen foam down to them. And if I've got four-percent oxygen, and I can have a breathable atmosphere inside our rescue POD at least 18 percent.

This is the oxygen transfer. As you can see, this is the size of 192 by 68 by 44 inches tall. It's small. It's 1,000 parts per million of CO and four percent methane and four percent oxygen. I could take that through my oxygen concentrator and give you 18 percent. That will give you some breathable oxygen inside of it.

What we're using is this is a, basically like a self-contained rescuer, that there will be 16 stationed inside of this POD. You will take two of those and plug them into the back, is what will actually give you your inside oxygen.

This, what we show here, you've got two of the personal O2 concentrators are in the back. Here's your CO scrubber and your dehumidifier. Once again, the concentration levels that are outside.

If we do have somebody that's injured on the inside of the POD, what we can do is actually put one of these oxygen concentrators on there and an 18-percent oxygen level. I'll give that approximately a 98-percent oxygen concentration, so I'm giving them almost medical-grade oxygen, without adding any other components inside of the rescue POD. It's just a little different approach.

As I said, there is going to be some heat that's going to be generated, 85 degree through a heat exchanger. We're going to put about 65 degrees back in.

This is pretty crude and rude and elementary, folks. As I said, there's a 36-inch opening. These are your seats. When I sat down in it, the roof almost touches the top of my head. There's some drawers underneath for some nutrition and a little bit of water. We've got to make sure that we do keep them hydrated.

You can see the construction. We're using I-beam construction. It's welded solid inside and out. So when they climb in, they pull the door, seal it, turn the oxygen units on, and start sending us some information and let us know what's going on. We will use our through-the-earth communication, and the same information we use for proximity protection to be able to know who's in the POD by their RFID identification.

It's mounted on a skid surface so it can be pulled along with the units. And it's pretty heavy, because we're using a lot of steel here. So as they drag the thing around and try to stick a scoop stinger through the side of it, then turn around and pull it down to crosscut and rib it out, and then try to slew it around and hit it with a shuttle car to push it into a crosscut, that's just the way life is in the coal mines. So it's got to be rugged to be able to live through all of that.

And in conclusion, utilizing the rescue POD for each mining unit could be a useful method for saving lives during a mine disaster. We could sit up here all day and talk about this, but we don't really know what's going to happen on each individual disaster. And let's hope that we don't ever have to go through those again.

Gamma Services alone, with all its supporting companies, believe our approach is one of the answers to saving lives right now. It's not the only one, but it is one approach.

However, if new ideas or guidance arises in the future, we'll change our direction to expedite the employment for lifesaving devices to the mining community. The last thing we want to see are more fatalities out there. I'm a fourth-generation coal miner, and every time I see one of those fatality bullets go up, it's just another notch that's hard to swallow.

Thank you.

(Applause.)

MR. FINFINGER: Our next speaker is Mr. Bill Kennedy. He's got the long CV, three pages, but I have to make it short.

Bill is from Kennedy Metals. His experience over the last 30 years has included the ventilation of mines and manufacturing of equipment. To do so, having worked on ventilation problems in more than 250 mines in the United States, Canada, Mexico, England, South Africa, and Australia.

He has worked on problems in mines of various minerals, including coal, salt, uranium, gypsum, gold, copper, lead, zinc, falspar, potash, et cetera. Problems he has encountered range from the application of yielding steel stoppings to assisting major engineering companies with insulation layouts for entire new mines.

Mr. Kennedy.

MR. KENNEDY: Thank you very much. Good afternoon. Thank you very much for being here to take a look at this presentation.

I'd like to show you today about the Kennedy chamber. But first a little bit of background. Some of you know me, some may not. My father, Jack Kennedy, started Kennedy Metal Products about 60 years ago. We're a manufacturer of mining ventilation equipment. Many of you would be familiar with the Kennedy stopping, or our overcast man and machine doors, that sort of thing.

We are very used to the nature of underground mine ventilation, and unfortunately, some of the difficulties that have occurred recently.

On the screen you can see the Kennedy chamber. I have two housekeeping statements to make. First, I'd like to advise you that the entire presentation is copyright 2006 Jack Kennedy Metal Products and Buildings, Inc., all rights reserved, with the permission hereby given for MSHA to put this presentation on the website.

The second thing is the presentation shows products that have patents granted or pending U.S. or foreign.

We have heard some things today about the use of chambers. And previous to this meeting, I've heard a number of things about chambers, and people's reluctance to put chambers in the mine because they were afraid people would use them when they shouldn't. And I want to make it really clear that no one at Kennedy is advocating anything of the kind. And this sticker is right by the door handle: Do not use the chamber if you can safely escape the mine.

But if you can't escape, you might want a chamber. This current, the chamber that you're looking at here and most of the chambers we design, is set up for 100 hours' duration, very quick initialization, and basically all you have to do is walk in the door. If the chamber is already contaminated for some reason, the house-type units have purge air, so you can exchange the air that's in the chamber for fresh air. And it contains on-board oxygen supply without chemical seat or ignition sources.

We at Kennedy are concerned that when you have an event in an underground mine, particularly a coal mine, we have to assume that ventilation has been compromised; and therefore, everything in this chamber and what we're talking about here, including the oxygen supply, is designed to have no ignition sources.

The design criteria includes the oxygen rate adjustable according to the number of people that are in the chamber. That's pretty important. CO2 scrubbing, that is just as important. You can't just put in oxygen and ignore the CO2.

The chambers operate under a positive pressure. No power is required. It's a mine-tough unit; it's designed to be used in an underground coal mine, and dragged around from one place to another, and so forth. And it's designed to operate without maintenance for five years.

As I said, the unit is tough. It's designed to be used in an underground mine. The skid design allows repeated movement, with a minimum amount of height. That thing is only 24 inches tall. A special hardened version is available as an option.

The hardened version you can see depicted here, it is the chamber that you saw initially, but with a heavy tubing frame around it to give it considerable structural integrity. This design will stand being blown around in the entry, at least to some extent.

We have an explosion test chamber at the factory, and we will probably test these in explosion conditions as we get a little further along in their development. I'm not sure that's a real valid criteria myself. If the chamber was blown around badly enough to tear it up, I'm not sure there are going to be too many people around to use the chamber.

Life support capacity for a standard unit is 100 hours. If it was used at half capacity, it would be 200 hours. I had a customer call me the other day, and he said well, I like that 100-hour, four-day design, but we really want five days. And I told him that's not a problem at all. We're going with more seats. If it is loaded to capacity, it would be 100 hours. If it was loaded at half capacity, it would be 200 hours. There is enough room in there, honestly, for about double capacity, so you could do that. If you had the people there and no place else for them to go, they would have about 50 hours.

The house-type units, we have three types of units that I'll tell you about. But the house-type units are the most appealing to me. They have an instant set-up time. Most of the time all they have to do is open the door and walk in. If it's contaminated, as I indicated earlier, purge air is available to blow the chamber out. Oxygen flow is started with the turn of a knob, and CO2 is able to be initiated in minutes.

The operation is simple. Purge the chamber if necessary, start the oxygen flow, deploy the CO2 scrubbing material.

Inside the chamber are very clear, simple instructions, including in this case even a drawing of where you put the scrubbing material on the ceiling. Everything inside the chamber is similarly documented. You can see here, although I'm sorry it's a little out of focus, what you're supposed to be able to see right there is something that says purge air valve. And by golly, there's the valve.

Everything in the chamber is designed to be very simple. Even if you didn't have training or just got hit in the head and can't remember your training, you could probably still do everything that's necessary to get this chamber in operation.

Purge we want to do very quickly. Discharging a whole lot of air inside a small chamber creates a lot of noise. We provide a purge-air muffler.

If you've got the inside under control, the next thing you'd want to do is start oxygen flow. It must be regulated according to the number of people in the chamber rather accurately. Too little, of course, causes hypoxia. Excess flow wastes chamber time, could cause oxygen toxicity, certainly will if you're in there long enough. And the time you start being concerned about is about 16 hours, and it creates a fire hazard.

There is an oxygen flagon next to the oxygen flow meter, you can see it here. And in this particular chamber, it's right by the window where the flow meter is. In this particular chamber, if you can read some of those numbers, if there were 10 people in this chamber, you would set it at five liters per minute.

The oxygen flow meter is a typical medical device, just like what you would see in a hospital. It's inside the chamber, and you can see the oxygen pressure gauge just to the right of it. The gauge to the left of it, sitting at an angle, is the purge air pressure. Both of these gauges, incidentally, are able to be viewed from the outside.

The third thing that you would do, of course, is to deploy lithium sheet scrubbing material. We happen to have a couple of lithium sheet experts in the audience today. If you have interest in that particular sort of thing, ask me afterward, and I can introduce you to them.

No power is required for a very long period. Hours exist between the time that you have to exchange the scrubbing material.

We provide, inside a sealed box that you see on the left, a mechanical timer. In the picture on the right is the timer box with the door open, you can see the timer in there. It's a 24-hour mechanical timer. It has a bell that rings. You can use that to determine when you're going to change the scrubbing medium.

It has a five-year commission life. Everything in the chamber is designed for a five-year life without maintenance. Routine inspection only requires looking at the outside for damage, checking the air and oxygen gauges, which as I indicated you can do from the outside, and checking the tamper seal to make sure that nobody has been in there.

The picture on the left, there is a good picture of the double oxygen gauge. One of those is facing into the chamber, one of those is facing out. And in the picture on the right, I'm sorry for the glare, but if you look just to the left of the glare you can see a portion of the purge air gauge.

Recommissioning is available at the factory, if you would like that. At their five-year anniversary, the oxygen and air cylinders must be removed and hydrostatically tested. That's not our requirement, that's not MSHA's requirement, that is a pressure vessel requirement. Would the chamber work afterward? Certainly, it probably would. But you wouldn't want to take that risk, and you certainly wouldn't want the liability. The thing to do is at that time, to have the chamber renewed. The provisions would be replaced, the damage would be repaired.

As I indicated, there are three types. This house unit, in my opinion that's the best choice, because it's always ready to go.

We have a folding house unit available that you can see deployed here. And I'll run through these slides relatively quickly, and you can see the chamber coming into existence, so you could get that thing up and going in a few minutes.

Its advantage is that when it's collapsed you could get it around low locations, and erection doesn't take any more height than the erected chamber.

Well, we also have available a skid unit which is the basis for the other two units.

MR. KENNEDY: It has all the provisions that you would expect and need, and it would have a space in it for barricade materials.

There are some pictures here. You can see the inside the cylinder arrangement. It has some energy-absorbing design to it in case of an accident in transporting it, escape windows, permissible telephone, chemical toilet, provisions that you can see here, including $300 permissible flashlights. There is a nice, bright interior with good seats, guest sampling ports. It operates under positive pressure. It has relief valves that continually purge the chamber and the air lock, and it comes with first aid, some repair materials, and is available with some DVD retraining materials and mobil chamber for training purposes.

I have run a little bit over. I am about to be frowned at. Thank you very much for listening to the presentation and coming today.

(Applause.)

MR. FINFINGER: His rescue chamber also got a red light flashing, so we show it to you.

Our next presenter is James Rau. He is qualified as a mining engineer from the University of Queensland in Brisbane, Australia, and he has been with MineARC since 2006.

At MineARC, he has been managing the United States division of the company, and providing metal companies with retimber variations. These assessments involve irradiating down into ground mines, current refuge chamber designs and capacities, escape route systems, ventilation, emergency preparedness and required numbers and locations.

Prior to MineARC, he run two of the of the new Australia operations, and he was responsible for completing refute timber due diligence and restoring MineARC's refuge chambers. James.

MR. RAU: Thank you. I'm going to keep this very short. Another thing, you can turn to my bios, I don't like public presenting, so we will start quickly.

What I wanted to do today was give you some background as to MineARC. MineARC has been involved with designing refuge chambers since 1994. They originally were requested by Western Mining Company to design one of the first refuge chambers. Now, this was a very basic system, had a scrubbing unit and basically a converted sink and turner.

What I want to -- right here is basically, in other words, leading developer and manufacturer of refuge chambers. These are a few of our major customers in Australia. As you can see, Newcrest, Newmont, Baouk, Satwad in Australia is our refuge chambers. There is over 200 refuge chambers in Australia alone.

Other locations around the world include Ireland, Sweden, Turkey, Canada, South America, Papua New Guinea, Indonesia and all of Australia. Of particular interest today is that we have one unit in a coal mine at Huntly, which is solar energy.

What I want to explain today is basically the two units which we have designed. One of them is for licensing insertion, the other is for standard cementry. We are currently manufacturing our standard cementry unit within Australia, a privilege to be sought in Australia and MSHA concurrently. Outstanding within Australia basically require that all equipment that goes in the coal mines is intrinsically safe. That is not the case here in the U.S., so effectively if you have the same height you could use our chambers in the coal mines. What we want to do is put best practice for down and ensure they are intrinsically safe.

We anticipate delivery to the U.S. within four to six months, and this is dependent obviously on the MSHA approval process, and long-term, we would like to manufacture within the U.S.

Now we have already spoken to private enterprises and we're looking to state government and centers and things like that as well, and anyone that would like to do a joint venture.

What you are looking at here is CRM64-inch units that has a standard 64-inch height. Because there is no compressed air in the mines here, it uses an air locking system. I'll go into it in further detail, and that's the one we are currently manufacturing.

This is our CRM24-inch unit. The top left picture you will see there it has in its collapsible state, the lower one is basically once it's been put into place. This unit would be brought into the mine on rollers. Once the area where it was supposed to be placed is found, they would have to mine it out, and that goes up to a height of 72 inches.

The scrubbing systems that we use in all our refuge chambers is the same essentially. We scrub for carbon dioxide and carbon monoxide. Obviously, it's to clean the air. It uses a series of chemicals actually from molecular products we presented earlier.

Now, the purpose is to remove the carbon dioxide and carbon monoxide from the air, reducing the risk of poisoning. Now, some of you might actually be thinking that the carbon monoxide is from external sources.

Do we have any smokers in the crowd? Anyone? Actually the smoke in endogenously-produced carbon monoxide when you feed them oxygen. Now, this was the process that was discovered by Monarch quite accidently, and it's a serious issue which hasn't been picked up by a lot of other manufacturers. Cigarette smoke will produce about 20 parts per million. That's an average cigarette smoker.

So in terms of calculations, what I'm got there in 10 hours the carbon monoxide will reach 2,000 parts per million in a 15-man chamber.

Now, essentially what that is -- that's assuming that you had 15 occupants all medium to heavy smokers. Now, this is a patented system of Monarch.

As mentioned previously, there is no compressed air within coal mines, so the initial source of oxygen supply is fed from medical oxygen cylinders. Following on from that, that's regulated for the number of occupants at half a liter per second -- sorry, half a liter per minute, and following on from that as a secondary source you have an oxygen candle. The oxygen candle is an exodemic reaction. It's sodium chlorite and it basically produced an enormous amount of oxygen in a short period of time. That also oxygen enriches the chambers which produced further carbon monoxide from the occupants.

The electrical systems, basically as I said we want to have them intrinsically safe. In stand-alone situation, they are designed to run on mine power. Once the mine power fails, a UPS battery backup system will automatically run the unit.

Now, our current chambers run for 36 hours. that's for the metalliferous industry. We can go anywhere up to 96 hours. You just need to add more batteries, more oxygen and more chemicals.

Another point that's been missed today which I think is extremely important is air conditioning. If you put paper inside a chamber and you don't tell the occupants, you will end up killing them. Every person gives off between 100 to 200 watts of light and heat. It's an enormous amount of heat. If anyone sat inside one of those older star refuge chambers that they showed this morning, they would be fully aware of it.

Okay, the air locking system, basically it ensures occupants can enter the chamber without contaminating other persons. It's a pneumatic system and it basically has a binary locking. So what would happen is the first person would arrive at the chamber, they would push the button. It would flush both the chamber and the air lock. Then they would move into the pressurized air lock. It would recharge from behind, and then the second door would open, so both doors can't be open at the same time, and it has an override system.

Okay, this is some details of our CRM64. As mentioned, it has a 64-inch overall height. It's essentially very similar to our current metalliferous unit except that it's intrinsically safe. Constructed of quarter-inch steel plate, and four-inch pressed-formed channel reenforcement.

Now, this bundle we normally put with a skid base and towing and lifting points and have wheels as optional. It will have internal and external real-time gas monitoring and also temperature monitoring.

Details of the CRM24. As mentioned, hydraulic, telescoping roof. Now, that 72-inch height is still something that we're questioning. We can bring that lower. It's just dependent on the height restrictions of the mine.

It's constructed of quarter-inch steel plate. The scrubbing system in this unit will be a little bit different because of the height restrictions, so it will be a closed system with everything pre-regulated. Essentially it would just be a push button system. It will be fitted with steel wheels and internal and external gas monitoring.

What you're looking at here is a prototype which Monarch built. It's a fire-rated refuge which will withstand 2,000 degrees Fahrenheit for 120 minutes. I won't go into too much detail. If anyone is really interested in it, they can ask myself or Jeff.

Essentially it has a cutting, it's got a quarter-inch paint and that expands when the flame contacts, stops the structure buckling, and all the scrubbing unit's air conditioning, batteries, everything is internal within the chamber.

Our future developments, we're looking at video camera imaging for internal and external. All this is to tie in with the mine rescue personnel so that they have the best information available to them in an emergency. Also alarms for power disruption. Basically that will allow the information from the chamber to be fed back to the surface. All of this is obviously contingent on the communication systems staying up in an emergency.

Contact detail, they've got brochures basically outside on the information bench if anyone would like to take one, feel free, and if you would like to talk to us when I'm not so nervous, it will be good as well.

Thank you.

(Applause.)

MR. FINFINGER: Our next speaker is Kimberli Tatton. Kimberli has over 10 years business sales and administrative experience. For the last four years, she has been working with mining health and safety solutions, working with one of the most respected mine safety professionals in the mining industry. Kimberli has joined forces with Lynn Sitterud of Modern Mine Safety Supply to design and fabric a refuge chamber for the underground coal mining industry.

Kimberli has a degree in business administration, and she is currently pursuing a degree in occupational health and safety with a concentration in fire science.

Kimberli.

MS. TATTON: Good afternoon. I am going to keep this very short and sweet so we can get back on track here. I have a fairly short presentation for you.

My name is Kimberli Tatton, and I am here representing Modern Mine Safety Supply, which is owned and operated by Lynn Sitterud. Lynn has over 20 years experience in fabricating, repairing and overhauling mining equipment and has done special projects for various mining operations.

Lynn has teamed up with Mining Health and Safety solutions whose president is Randy Tatton. He is a nationally-recognized underground mine safety expert, and they have joined together to design and fabricate what we believe is a unique mine refuge chamber for the underground coal industry.

The outside of the chamber is fabricated from quarter-inch steel with welded joints, and there is a dual-sealed air locking door. The unit is likely to withstand fairly substantial secondary explosions and is designed specifically for the unique needs of the underground cooperation and as completely customed, which means it can be used in any operation given their coal height.

Inside the refuge chamber, we are using the refuge 1 scrubbing unit which was designed and built by Rand Medical in Canada. We are also using medical-grade oxygen cylinders, and have available backup oxygen candles.

The air conditioning unit is there to combat heat and stroke which has been shown to actually impair decision-making, so it is very important that these units do have the air conditioning units in them, and the inside of the unit is bright, it is lit with fluorescent lights which runs off of the battery system. It is continually powered by a 120-volt direct source from the mine, and once power has gone out it is powered by 24-volt battery.

Like I said, it is completely customizable for any operation size or needs, and we are currently in the design process to make it intrinsically safe.

It can be outfitted with any operation's individual communication needs, whether they are using the PED system or any other communication system.

This unit is fully portable. It has wheels that make it easily relocated to support the mining operation as it progresses. Inside the unit is fully equipped with any food and water supplies that are needed as well as a first aid kit with blankets for shock treatment, structures and other necessary first aid implements. There will also be fire extinguishes, alternate light sources like flashlights and batteries or chemical light sticks, cards, pen and papers, which have been shown to relieve stress and tension for the occupants within the chamber; environmental sampling capability, which will be capable inside and outside of the chamber itself; as well a separate sanitary facility within the first chamber like there is sanitary facility for people to get a little bit of privacy while they are in the chamber.

Quickly, we have developed a fully self-contained mobil and modern mine refuge. We think it's unique for the coal mining underground operation. The cutting edge of technology to further enhance emergency response capability, refuge chambers will provide an additional alternative to escape during mine fires or explosions.

If you have any questions or want any details about how we can customize this for you, please look to myself or Lynn Sitterud who is out in the audience. We will be happy to answer any questions for you.

Thank you.

(Applause.)

MR. FINFINGER: Thank you. This is the end of this session. We would like to continue and do the panel discussion 5, the session 5. I would like to thank all the presenters in my session. I think they have done very well. They all kept their time, and I would like to invite Jeff to come and introduce the speakers, the next speakers.

MR. KRAVITZ: Okay, coming down the home stretch here, our first speaker for the next session will be Professor Jim Joy from the University of Queensland. He will be speaking on risk management for the mining industry. Dr. Joy is professor of mining safety and director of Minerals Industry, Safety and Health Center at the University of Queensland.

The center was established in 1998, with the support of major Australian mining companies and the Queensland government. MISHC is a national center active in education, applied research, consulting, and the development of the mineral industry's cooperative initiative, funded by the Minerals Council of Australia.

Jim has worked on many industry risk projects across Australia and overseas. He also presents papers, seminars and courses on risk management and human factors as well as developing resources such as safe mining handbook for the 2003 National Minerals Industry and Risk Assessment Guideline, and the 2006 Risk Management in the Minerals Industry Guideline.

Jim has also been involved in corporate and board-level advisory roles to BPHBilliton, WMC, and currently Extrata as well as been a panel member of the 2005 New South Wales Mining C3U. Dr. Joy.

MR. JOY: Thank you.

(Applause.)

MR. JOY: Thanks for the opportunity to be here and thanks for hanging in for the whole day. I feel like I could go home and design a rescue chamber after this having knowing very little about it before, but it's been terrific.

I'm going to switch gears probably considerably from the last session because my center is a not-for-profit sort of -- it's a center that was set up by the industry. It's been around since 1998, as the introduction said. It's always been 100 percent funded by companies, and those companies, these days we get about a third of our funds through the Mining Council of Australia, which is similar to your own National Mining Association, as well as the research consulting projects for industry as well as education.

I had been honored to do a two-and-a-half-day seminar on risk management in the minerals industry about six weeks ago at Pittsburgh Research Labs for NIOSH and it was great, really enjoyed it, put 40-50 people in the room. I'm going to try and compress some of that down to about 20 minutes of what risk management is about, focusing on, I guess, two things: one is this is what a mine manager gets taught to be able to be a mine manager in underground coal.

There is a five-day course that every underground mine manager in coal and metalliferous have to take in risk management, so I'm going to give you a little slice of what they have to take to get a ticket to manage a mine, which is all about their competency to make decisions about managing major hazards, including the emergency response and rescue aspect, because actually they are the people that will make a lot of the decisions or be involved at least in initial response and decision-making in an emergency situation.

Secondly, I am going to focus the discussion of risk management on one area of it, as the title says in the slide, managing major hazards, and those are by definition in my definition multiple fatality potential hazards in the minerals industry.

As I said, we were set up in 1998, and initially, as the bottom line says, we were set up by companies. Seven companies funded the set up of the center for the first five years because they felt like mining engineers didn't know enough about managing safety and health risks, and they needed to learn more about that while they were still students in the university and before they graduated.

So we started off and developed quite an extensive program. That's our program to date. A lot of courses down the right-hand side of the screen that you can get various levels of paper for, but the thing with the red box on it, risk management with a bracket G3 after it is actually, as I said, a requirement to be able to get a mine manager's ticket. If you have one already, you still have to take the course.

It's a five-day course, and you can imagine a 20-year experienced coal mine manager showing up for a five-day course on a Monday morning. He doesn't like me very much, that's for sure, but by the end of the week normally it's an interesting week because we are really challenging thinking about managing hazards and trying to deal with changing naturally human reactive mind-sets to much more proactive and prevention-focused thinkers in the management of the mines.

The course is run about once or twice a month, and has been for the last three years. We have put more than 300 people through the course, and there are only 50 coal mine managers in eastern Australia.

History of disasters, as Dr. Oberholzer mentioned this morning in some of the disasters that occurred in Australia and elsewhere, has driven the industry in Australia to look at major hazards as a separate problem to be dealt with. The picture on the left is not one of the ones on the right. That, of course, is Freeport, and you would have sen that I'm sure before. The four events listed on the right are ones in order that Dr. Oberholzer mentioned, the Moura explosion this morning, but there are other events, and that's in time order from the oldest at the top to the youngest at the bottom, all during the last 15 years, multiple fatality events, single multiple fatality events in metalliferous mining.

We have a decreasing fatality rate in Australia. Risk management has been a part of an approach to managing risks in Australia over that time period. It probably started in terms of discussion in the early '87-88 period, a similar sort of presentations like I'm making to you were made in that period quite frequently through to, as I'm going to talk about, the use of risk assessment and risk management integrated into the regulatory requirements, later adopted by companies in a way that was much more detailed and much more extensive than the regulations required.

But as you can see, if you do a line through that you wouldn't get a significant, although it does look significant, it doesn't come out to be statistically significant, but it looks like a pretty good trends, and I haven't got the last two years, but they are quite similar.

Note that that's in per million manhours and yours is 200,000 here, I believe.

This slide is meant to sort of illustrate a regulatory approach. It's meant to show a continuum where the left side is prescriptive regulation, that is, prescriptive about the detail of how you manage hazards, and the right end of the continuum is the enabling regulatory approach, and that is one that's purely duty of care.

Do whatever you need to do to make it safe. The government is not going to tell you anything about how to achieve that.

Where we are right now in the Australian minerals industry is in the middle, where the government is prescriptive about process, not so much about the detail of managing hazards, although there is still a fair amount of detail and regulations in various states. Really what you are doing with integrating risk assessment/risk management is saying the government is prescribing how you make decisions. Decision-making is what it's all about, and somebody mentioned it earlier this morning that the way we reduce risks is we make better decisions. So the government sets the approach.

Now, some of the ways that the government sets approach where the regulator then becomes a cogent or an auditor of that approach and the industry basically decides what to do. Some of those manifestations are having generally the principals of risk assessment and risk management in the acts and regulations. In other words, saying that you must understand the hazards.

You must assess the risks. You must put in the appropriate controls. You must think about the hierarchy control, which was mentioned by Ian earlier, the elimination through to personal protective equipment of five or six steps in the hierarchy of control. You must have certain competencies in your workforce related to risk assessment/risk management.

The second aspect is the -- what I will talk about as major, and that should say major or principal hazard management plans. Excuse me, I left out a word there. But say hazard management plans in New Wales and Queensland, and you must have major hazard management plans, or they are called principal in the other states, for certain hazards such as outbursts, such as gas, such as roof falls and those kinds of events.

You must also have a competency in risk management, and one of the ones I mention to you was this risk management for mine managers or other competencies in risk assessment and risk management in Queensland, and in some states there is also a requirement if you want an approval for new equipment to come into an underground mining environment, especially coal, or if you want an exemption for existing regulations, risk assessment is the way that you demonstrate that that approval or exemption should be accepted by the regulator.

So you're looking at a fairly extensive integrated approach to risk assessment and risk management, but I would hasten to say that the regulations are evolving, and there are limitations to risk assessment/risk management that we could talk about if we had a lot more time.

What I wanted to get into specifically this major hazard management approach. What you are looking at on the screen is just a basic model of what you're suggesting should be done with a major hazard or any hazard, but I would say major hazard.

You've got to identify them. You have got to understand them. If you have got me saying you've got to identify it, understand it, make sure you understanding the levels of methane, where it might exist, why it might exist, and it would be the same for in-rushes or any similar event, identifying the hazards especially when there is a fair amount of uncertainty is a critical step to risk management.

Then analyzing the risk is looking at what can go wrong, how likely it can go wrong, what are the consequences if it does, and from that trying to identify the right level of control. There is no zero risk.

So some hazards you just, and risks you put up with because the risk is acceptable. Sometimes you can't do something because the risk is too high. In the middle you have this aspect of control. Managers are taught to go through the process of thinking, to learn to think this way about hazards, and to put in those controls, monitor the performance of those controls through auditing and performance management, and also to look out for change.

Change is a major factor, of course, in the mining industry, and it's something that often is a contributor to major events. A hazard is changed. The risks changed. We missed it, and we blew up the mine.

The control framework mind-set that you teach mine managers is a four-part approach, and of course we've been talking a lot about emergency response and rescue, which is at the right end of the model, but of course we want the other three parts too. We want the manager to think in a continuum of response to a hazard from prevention and monitoring of conditions and important controls, through to first response, or as they call them in Queensland, TARPs, trigger action response points; points where the CO level goes up to a certain point, and we start to take action. We don't wait for it to get too high or methane to get too high, and that applies for every major hazard.

We look for ways that we can identify early in the development event that we are on the way towards potential major event, and my managers are taught that they should be thinking that way about every hazards: find that trigger, look for the early warning so that you can do something before you start to progress towards a major event.

And of course the last bit is should it all hit the fan be prepared, whether it be with chambers or whatever the technology that's required for that particular hazard.

I would note here that it's pretty easy to see when you do a fair amount of risk assessment, as I've done over the last 20 years, that sometimes the emergency response isn't very well thought out specific to the hazard and you get conflicts in mines like, for example, their emergency egress is great for -- is good for a mine fire but it's lousy for an in-rush.

So why do this major hazard management planning? Well, obviously we want to focus as an industry on the big killers, on the high consequence events, and make sure they are under control. They are low probability/high consequence events, so by human nature people may not think about something that hasn't happened before, but could. The infrequent event is harder to manage than the frequent one.

We want to do that in the most effective and efficient manner. In other words, we want to make sure we are focusing on priorities and spending our dollars where it's most important. Risk assessment will focus you on the most important issues and the most important controls.

Of course, it's to meet regulatory requirements in some cases, but I could give you a list of companies that have gone well beyond that and use the same technologies in a lot of different areas where they have major threats to the success of their business.

So in the Queensland regulations, you end up with a list of specific issues which are considered to be major hazards. This was a decision post-Moura to basically say there are certain major hazards that there must be a risk assessment-based major hazard management plan for, and a process to achieve those plans, although not defined exactly in the regulations is inferred, and the general good process is to, of course, find those hazards, review them, location, risk controls, and then to manage with that information which can often be that we do the analysis but we don't do the management through documentation, action plan, standards, setting accountabilities, certainly putting things in place, and the two last steps are actually extremely important: monitoring and auditing to make sure things are there that are absolutely critical.

Again, remembering that the infrequent, high consequence event is a very easy one to not think about in the day-to-day pressures of managing in a mine, so we have a particularly -- the major hazard management plan establishes a particularly formal documented approach to managing this hazard that says we must have this, and we have got to check it. Even though we don't think it's going to happen, we've got to go out and check it regularly whether it's through monitoring or auditing, and we must have a formal change management process.

If something changes, whether it be the hazard or a control or a competency, we've got to review where we are because this very infrequent high consequence event demands a higher level of management system than we use for the rest of our operations, and that's what drove the whole development of this approach.

The industry recognizing that management systems were not particularly robust in coal mines, and the major hazard management planning approach is much more robust. It is an artificial management system really, and probably in some mines you don't need it anymore in Australia, and perhaps other parts of the world because there are other management systems are more robust.

But where the management system is not robust, and that is that accountabilities are not clear, auditing and monitoring is not a regular part of duties. Change is not managed well, creating this artificial management system greatly increases the likelihood that you will prevent and be prepared for a catastrophic hazard.

Risk assessment is a key part, of course, of developing a major hazard management plan, usually at two levels. Those of you that are familiar with risk assessment, I'm just going to touch on this quite briefly.

The terms "risk assessment" or "risk analysis" are juxtaposed in Australia. Risk assessment refers to a method like HAZMAT or a formal technique that looks for hazards and risks, analyzes the risk, and then decides on controls. So what I mean by this is those kinds of techniques, the high-level broad-brush technique such as preliminary hazard analysis or "what-if" analysis is used initially, and then from that you identify the things that need more detailed analysis in major hazard management planning such as if you had an underground fire potential, an underground metalliferous mine, you would do much more detailed analysis on a fire in that location once you've done the broad-brush analysis that said in this mine the major potential events are these 10. Let's look at those in much more depth, and create either individual plans or one major hazard management plan.

So tools like fault 3 analysis commonly used in many industries developed, I believe, in the U.S. military missile project back in the fifties as a technique to take a significant unwanted event and understand all its contributors, very commonly used for major hazard management planning in mining.

So what this top event might be a fire underground causing multiple fatalities, so what you're doing is a deductive logic technique to try and say what will be all that causes the fire, its propagation, the lack of escape, and you identify all the potential contributors so that you can then look at each one and say do I have controls that are adequate for all of those contributors.

Another common technique, probably less common and simpler is the bow tie analysis technique that was developed by Shell as part of their -- the name slips my -- Tripod, Shell Oil's Tripod Program back in the eighties, a technique to help people look at an event, not the worst-case event, the top event in this would be a fire starts underground where the left side of the bow tie you would use -- it's just a schematic here -- but to and thing of what are all the causes of a fire underground that we could have, and therefore what are all the threats and the controls that we have in place, or need to have in place to make sure we don't get that fire.

The right side of the bow tie is to say should we get a fire, what are we going to do, what are all the consequences and how do we control for all of those.

It's a very simple illustration of the logic and most of the time risk assessment is not about crunching numbers to four or five decimal places, it's really about asking a logical sequence of questions that simply challenges people in terms of their understanding of a hazard and challenges the organization to make sure they are ready.

With all that analysis, we get to the framework that works and put it into the plan.

Just quickly to close off, an additional layer to this sort of major hazard management plan is actually the industry trying to work together to contribute information to each other, so we learn from each other. We share our best practices.

So in Australia, we have the Minerals Industry Cooperation Initiative for the last three years. We're just setting up for the next five. The idea is to improve industry risk management, and this is sponsored by the Minerals Council of Australia, which is similar of course to your National Mining Association; in other words, 29 mining companies belong to this.

What we are trying to do is the hard products of the last three years, which are now available, try to help the individual mine through computer access, access guidelines on risk assessment and risk management so the know how to design a risk assessment and they know how to do risk management.

MIRMgate in the bottom left is a best practice guideline database. You can access online and it has 1,500 publications in it from around the world, including a lot of the American MSHA publications that are available. Professional pathways tells people where to get competency in the sort of thing I'm talking about, and of course, we are trying to work on the bottom right, which is the database of lessons learned, but I have to kill a few hundred lawyers to be able to get that one going, so we're still working on that.

You can access our site at that address. If you want to look at the resources, they are owned by the industry, by the companies, and they are endorsed by the regulators, and we try to work cooperatively with the regulators and the companies to develop these things that are optimal for the industry.

The next thing that will be on there will be a risk management guideline which will help people chart their path to move from vulnerable reactive management approaches through to their fully resilient integrated risk management ideals that are set in some textbooks, and are presented by people like Western from Michigan, and the University of Leiden, a professor there also has a model similar to this which just basically helps a mine or company chart an approach to improving their risk management over time.

So I went through that very quickly. Just a closing slide. I'm pretty proud. I'm not Australian as you noticed. I am Canadian. I have been there for 20 years and I have always been in mining since I've been there. I wasn't in mining when I was in Canada. I was in nuclear power stuff.

But Australia has adopted risk management, not only the regulators, but the regulators did it first, and then the companies came on board with it, and they saw value, and they picked it up. And what you're looking at just briefly is improvements.

The top one on rock fall potential and severity in a WMC mine that went to risk assessment-based ground control standards basically went from a significant problem in actual and potential outcomes to almost nothing, and the bottom one is outbursts in a coal mine where it used to be, in 1986 and '87, somebody got killed by an outburst, people would come on TV and say, well, that's just the way it is in mining. You get killed by outbursts. These days there hasn't been an outburst since 1994-95.

Thank you very much.

(Applause.)

MR. KRAVITZ: Did you think you were taking your life in your hands in that last comment about the lawyers. Half the audience that's left are lawyers. The other half wishes they were lawyers.

(Laughter.)

MR. KRAVITZ: Maybe not.

Okay, our last speaker today is proud to be the clean-up batter. She likes that. Good. Kathy Kowalski-Trakofler is going to speak on psychological and training aspects, specifically she has a strong niche here, I don't think anybody else addresses it the way she does, and she has a fantastic job at doing this type of work.

She has been a research psychologist at the Pittsburgh Research Laboratory since 1991. Received her Ph.D. in counseling from the University of Pittsburgh, her M.S. in counseling and behavioral disabilities, and B.S. in education from the University of Wisconsin-Madison.

Her research interests include human behavior during emergencies, work stress, judgment and decision-making during emergencies, and issues on non-emergency communications.

Dr. Kowalski-Trakofler is the mental health advisor to NIOSH, Office for Emergency Preparedness, and I keep calling her Kathy Kowalski. Fake everybody out. Okay, please welcome Kathy.

(Applause.)

MS. KOWALSKI-TRAKOFLER: Thank you very much. I hope that, I would like to think that you saved the best for last, but I'm a psychologist, it's the end of the day, and I know that I'm the outlier here. We are just about to do 180 degrees in terms of a lot of the information that you have gotten the last many hours.

I would like to acknowledge my colleagues at the Pittsburgh Research Laboratory who have done work in this area in the last 10-15 years, looking at behavioral aspects of miners and escape.

I want to begin by putting this within an historical context. When we are talking about escape behavior, it's not new. Actually reported history, it goes back to approximately 603 B.C.

We're discussing behavior under stress. This falls into the discipline of disaster psychologies. Studies of military experiences, police, emergency and medical personnel have provided most of the data for this particular area.

In the 1960s, research began to be done with the police departments, and also in general human response to disaster. The disaster mental health area was exploded in the 1970s when Dr. Korentelli developed research institute at the University of Delaware.

The Vietnam War brought attention to the psychological issues with a medical diagnosis of post-traumatic stress disorder, and it then became common parlance that there were psychological issues that needed to be dealt with in disaster. After 9/11, the research has exploded expidentially in this area.

What do we mean when we talk about the psychological aspects of escape and sheltering? What we do not mean, and I want to emphasize this, is we are not talking about counseling, we are not talking about psychotherapy, we are talking about individuals, normal individuals who are put into an abnormal situation, and we know what some of those responses are.

Understanding this very natural, normal human response to danger provides escapees, command center personnel leadership, mine rescue team members with an ability to be more resilient in an emergency situation, and that is our goal.

An individual during an escape is experiencing normal symptoms of the fight-or-flight response. One of the earlier speakers referred to this. This is the innate response that prepares us to either fight or to run. There are psychological, physical behavioral and cognitive components to this response.

For example, and I'm not listing them all here, but it's important to think about this with respect to those miners as they are escaping, increase in heart rate, muscle tension and perspiration. In many instances, there is hyperventilation which creates a rapid heartbeat, shortness of breath and in some instances nausea. This is where miners have reported to me that they feel as if they are having a heart attack.

The pupils dilate, again getting ready to run or fight, the mouth gets dry, and there is numbness in the hands and feet. This is usually attributed to the fact that the blood is rushing to the center of the body to protect the major organs.

In addition, there is fatigue, and the fatigue is not just physical fatigue, it's an emotional fatigue. With physical fatigue, many times there is a release. It's like those of you who are runners know that you are fatigued after a run, but there is also a release. Emotional fatigue does not provide that kind of release. There is also confusion and fear.

There are different phases of a disaster that organizations experience. There is the initial impact phase, and this is a phase where you can't quite believe this is happening. This is also the phase that, as again was mentioned earlier, people tend to try to normalize. They initial response to a situation, for example, the belt fire that was mentioned this morning, is to try to normalize it. Oh, that can't really be a problem. It's not that serious. Because of this we lose precious time in response.

The next phase is the heroic phase. This is a phase where people are helping each other. This is where the miners will be working together helping each other to try to escape, to try to get out. In other disasters, this is where the normal citizen passing by will come in and rescue somebody.

Then we move to the honeymoon phase, and this is where there is relief. I made it through, I'm alive, everything is going to be okay.

Then we move into the disillusionment phase, and that's the phase where all the questions come up. That's the phase where we start to ask the questions to find out how did this happen.

Finally, there is a reconstruction phase. It's been suggested that emotionally the major impact is six months later. What this means is when a disaster is over, which many in the mining industry think when it's over, it's over. When we either get the people out or the mine is back in production, it's over. This is not true from a psychological perspective. Actually, sometimes, as I said, six months later this phase is just beginning.

The stages, individual stages that people go through after that initial disbelief, after that initial trying to normalize, there is shock. When the recognition that there is danger, shock and disbelief. Then there is a very strong emotional response. This can take many forms. Sometimes people get angry. Sometimes people will withdraw and become very quiet, but there usually is in some way or another a very strong response internally or acting out.

Following that, there is acceptance. The individual realizes that the incident happened. They are going to have to accept it into their lives. Finally the phase of recovery. These are not linear. They don't happen one after another. People move in and out of these, sometimes over a long period of time. And recovery does not mean that we're back to normal because after a traumatic incident there is no back to normal. What happens is there is a new normal.

Short-term psychological symptoms, symptoms that you can expect from someone after they have had a traumatic incident, and this is usually within immediately afterwards and within the next three months. This applies not only to escapees, but this applies to people in the command center, rescue personnel who have worked many long hours. There is a numbness. There is a denial. A lot of times people simply don't want to talk about it. They will evidence-avoidance behavior not to talk about it.

Some miners who have escaped under duress don't want to drive back down the road towards the mine because they sometimes will get flashbacks.

Again, difficulty concentrating is very normal. This is not a time to make any major decision. Withdrawal of behavior, acting out of behavior, relationship problems, depression, not necessarily clinical depression in the first couple of weeks, but feeling down, feeling depressed is normal, feeling overwhelmed, expressions of anger. Many times there is an increase in alcohol consumption, change in sexual functioning, and many times change in eating habits.

Now, these are short term. They can take effect any time immediately after the incident to up to three months.

Long-term psychological symptoms are much more serious, and this is after three months, usually after six months. We hear so much about post-traumatic stress disorder, but that diagnosis is not relevant until three to six months after an incident when symptoms such as fearfulness, sleep disturbance, consistent flashbacks, feelings of guilt, and that includes survivor guilt for people who survived when their buddies died, generally high anxiety and irritability, and many times an exaggerated startled response. If there is a loud noise, particularly if the incident was an explosion, people will have an exaggerated response.

Post-traumatic stress disorder is a medical psychiatric diagnosis and it's based on some or all of the following: certainly a traumatic event and re-experiencing that traumatic event; numbness and avoidance, which we talked about; hypoarousal symptoms, which is the startle response.

Psychiatric disorders are diagnosed on duration and intensity: how long are the symptoms persistent, and how severe are they? Are they interfering with normal function?

The RAND/NIOSH report after 9/11 looked at responder behavior, and this is very important because I know this is talking about escapee behavior, but human behavior is human behavior, and it's relevant in many different circumstances and situations, and we need to take our mine rescue personnel into consideration when we look at some of these very basic human responses.

Stress affects responders' judgments, and many times they will take high risk. We've heard some people talk about this morning. We found this true in 9/11, some of the recent research that we have done in this past year with interviews. I've heard particularly mine rescue personnel many times say they take additional risk when there are people involved, sometimes to their own detriment.

We send our people in, our people who have been exposed to major events, see many times some horrific events, horrific events and see horrific things. I have had mine people talk to me about seeing body parts, and these are traumatic events.

Of the five senses, smell lasts longest in memory. That's something that you probably didn't know. But because of this, even years afterwards there will be flashbacks with certain smells, particularly a burning type smell. I've had people talk about 20 years later going back to an incident that happened in a mine.

Visual sense is the next sense as you might have guessed, and these also can trigger flashbacks many years later. We recently have completed collecting the data on a study in the last year because we were interested in what happens in those first critical moments, we were particularly interested in initial communications after a disaster or when an emergency is identified as an emergency.

What we did is we went out and we interviewed experts in mine emergency response all over the country, and we also did some focus groups. We talked to people at the mines who had experienced disaster and managed them, and we also talked to mine rescue personnel.

It was very interesting. The data fell into two very distinct categories. One, the mine rescue data, and two, the on-site data. Mine rescuers get there later. They aren't there immediately. So what happens is very different, and their perceptions are very different in terms of issues like communication.

We asked open-ended questions so we ended up getting the story. We looked at first reactions. We wanted to know what their first reactions were, what some of the first decisions were that were made, some of the information that they needed, and finally, what kind of recommendations they would make. We wanted a lessons learned opportunity.

This is an ongoing study, and I'm just going to give you a couple of the highlights. We're really just at the tip of the iceberg here.

One of the key issues that surfaced was the issue of judgment and decision-making. Information must be accurate, and several of the experienced mine managers told us that the first thing that they would recommend is stop. That's unusual in an emergency to stay stop. You're in an emergency. The goal is to move forward, go ahead. But these seasoned mine emergency managers said stop, assess, make sure that you have accurate information because the decisions that you make impact the outcome.

They also talked a lot about the source and how the source affects decision-making. If it's old, seasoned miner Joe who is calling out, and is sounding very panicky and concerned about the belt fire, there may be a different reaction than if there a red hat or a rookie calling out. So the source of information again is something that became very emphasized in the interviews that we did.

They also talked about the fact that stress and fatigue many times led to poor decisions, and that this is something that certainly is evident in the command center with the adrenalin pumping, people are not always relieving each other as they should.

Another issue that came up was trust, and many people, not only in the on-site mine emergency personnel, but the mine rescue people talked about the issue of trust and that in some instances it's more important than protocol; that you are going to call on somebody that you trust to take care of an issue that you must get done even if protocol calls for someone else in that slot.

Trust is built through working together, and training together. Psychologically preparation is the most important activity in which to engage after a disaster. The question becomes what can we do to prevent or mitigate such an event. We're doing that today. This is a very important event.

Information lowers anxiety in planning quiets fears. Training, training, training, we've heard about training a lot today. In the research that we have done recently, we continue to hear about training and the key part training plays. Knowledge is power.

We heard a lot about instinctive behavior. You hear people say, well, I just did it. It was instinctive. It was a natural thing to do. I'm probing that. What we find is that instinctive behavior is the result of training. Adult learning is active and problem-centered, and it's important that in training that we utilize the principles of adult learning. Training together, again, builds trust.

Recommendations: Include community mental health professionals who are trained in disaster mental health, and I hope you note the difference between general mental health and counseling psychotherapy and disaster mental health. Disaster mental health is information. It's information about the normal behavior under duress, normal human behavior under duress.

Develop a curriculum to train mine personnel on the human stress response. We know this. This needs to be part of our training for disaster, for escape, so that people can understand the normal response. If you've never had an SCSR on, and don't understand it gets hot on your chest, if you don't realize that it doesn't inflate, you can panic, you think it doesn't work, and you can take it off.

We also need to do training in judgment decision-making skills, normal group escape behavior and leadership in mine escape. In NIOSH, we have done some work on leadership behavior that is of interest, and that could be part of a curriculum.

We need to study the psychological aspects of sheltering. We really don't know a lot about the psychological aspects of sheltering. We really haven't studied it. We at NIOSH have done some preparation of training materials for a shelter that was built in the mid-nineties out West, but we really haven't studied what happens to people when they are sheltered, when they are in a situation like that.

Finally, I would like to thank you for your attention. I hope that this 180 degrees has raised a consciousness of the importance of looking at human behavior along with the technology as you look at mine escape.

Thank you.

(Applause.)

MR. KRAVITZ: Okay. Now as promised we are going to have five panels with questions. I would invite Kathy and Jim to stay up there because I have a couple questions for you. I'm sure we will have some from the audience.

We're going to try to go through the questions that were asked by the cards first, and then we will take questions from the audience, but as promised, we will handle Jerry's question. I also would like to invite Mr. Van Zyl up for the panel, Mr. Oberholzer, and Alex Gryska, and John Kovac.

Very good, come on up here. Come up here by the panel. Thank you for volunteering.

Before you leave, we have compiled -- Maria has done it, well, we have been having fun out here -- she has been compiling a list of all the attendees, and please get a copy if you want it. John Gibson has them down there so should have enough for everybody. If not, we will make some.

Okay, is Jerry still here from Ocenco? Okay, do you want to come up and we'll ask a question. I want to have some ground rules though. I'm going to give you two minutes to have a retort, and Mr. Oberholzer, can begin. Is that microphone on? I think so. I don't want the debate to last the whole session. You understand that?

MR. STICKER: My name is Gerry Sticker. I am a national sales manager for Ocenco, Mining Division. During the presentation of Mr. Oberholzer -- I'm sorry, I have trouble pronouncing your name -- I heard through your presentation 100 miners died because they had wet hands and could not open the Ocenco SCSR.

MR. OBERHOLZER: Mr. Stickler, I have thought about it rather long, and I do not know at which stage I could have said that. I would like to reiterate what I said: that during one of the exercises, a very well-made designed self-riskier could not be opened by people. This does not, and I reiterate, that this does not reflect badly on your project. It reflects on the ability of people when they are under stress to do things that people would think is normal. They cannot do it. Their hands, they were wet, they were stressed, their eyes were closed, and they couldn't open the self-riskier, whether it's yours or whether it was a cup of coffee. They just couldn't open it.

MR. STICKER: On our unit, it's designed with two opposing nylon straps. You pull the straps apart and the unit opens.

MR. OBERHOLZER: Sir, I have seen them not being able to open a normal self-riskier. It's not an indictment on your product. It's an indictment on the situation when people are trying to save themselves. They have just walked for half an hour, they are walking hard. I think in this case they were about 18 inches deep in mud, and they were wet.

Now, the fact of the matter is the fact that some of those boots got pulled off their feet while they were walking in the mud is not an indictment on the boot, and further than that, sir, I cannot offer any advice.

MR. FINFINGER: Okay, thank you, good.

We have a question from Mr. Gryska. Could you tell us what was learned from the Westray Coal Mine disaster?

MR. GRYSKA: From the Westray?

MR. FINFINGER: Westray, yes.

MR. GRYSKA: The Westray disaster was the incident that occurred in Nova Scotia. Certainly the findings in that particular incident were failures in the system as a whole. To go into the details of the Westray, frankly, it would take considerable energy.

The findings in that found fault on everybody involved and right from senior manager at the operation, the enforcement agency and everybody else. Whoever is wanting information with regards to it, what I can do is give them a transcript of it and they can read it to themselves. It's a very complex issue. If they would like to contact me, I'll be here for the next few minutes.

MR. FINFINGER: Okay, thank you. Next question.

MR. KRAVITZ: Okay, this is for Mr. Van Zyl. With emphasis placed on refuge chambers, rescue rooms, this could be putting people, miners at risk. I would think that these chambers should at least be the last resort, which I think everyone is emphasizing here, only when egress service is impossible, so if you would like to comment on that.

MR. VAN ZYL: Yes, I think this was mentioned earlier that the goal would be egress. But when this issue was investigated, it was found that the condition for the amount of people underground exits from surface, but at that particular point in time rescue bays were the best and the most effective manner of actually ensuring that the workforce reached the rescue bay and then get retrieved from that.

Again, saying is it -- I think it's time that we revisit the strategy that's been put in place and maybe review its efficiency.

MR. FINFINGER: There is a question here, we think this is for Jim Joy, but if anybody else would like to answer, you're welcome. It's a very general question.

What are we doing as to prevention? Yes, Jim.

MR. JOY: That's a general question, yes.

(Laughter.)

MR. FINFINGER: Do everything possible.

MR. JOY: Does somebody want to be more specific about that question?

MR. VAN ZYL: Maybe I can explain this a little bit.

MR. KRAVITZ: Yes, basically they are asking about flame resistant retardant conveyor belts. You know, as sort of risk analysis goes, more efficient controls, slip switches, more effective electrical controls, effective CO warning system, monitoring systems, you know, that kind. So that gives you a little more information.

MR. JOY: Yes, you can certainly take a model of the four different levels of control from prevent through monitoring through first response and emergency response. We've been talking a lot, I guess, mostly at the emergency response end, and you could list out, and we went through mostly chambers, but we talk about a lot about refuge-base, but we talk about a lot of other things in that context.

You could develop a list for every hazard almost as long in all three of the other areas, and the first response area is the area that is developed a lot in Australia, and that is, monitoring systems, real-time monitoring systems which you have of course which define interiors for various gases. We are looking at real-time monitoring systems even for driver behavior in large trucks, using Caterpillar's Minstar system so we can actually look at triggers for behaviors as well as gas, that tell us the behaviors or being erratic if a person is on a 12-hour shift, or in the seventh week of a 12-hour shift every day thing, some subcontractors in northwestern Australia has got them working.

So it would take a long time, and you could make a list of all the innovations and preventions, I suppose, related to underground fire, as someone mentioned. Monitoring, things that we monitor, not just the gas, but we actually -- the innovation probably isn't monitoring the gas. Innovation is monitoring the controls that are important to keep the gas where it's supposed to be, in the first response area. That's about all I can say.

MR. FINFINGER: Okay, thank you.

MR. VAN ZYL: Maybe I can just add onto that is he just indicated that escape was research quad activity search 15 years ago. Since then major efforts have been to prevent disasters, specifically around explosions. A lot of work has gone in, active barriers, passive barrier systems, fire retardancy, monitoring systems, where do you place these systems, et cetera, et cetera.

So in South Africa, the focus for the last 10 years has been on prevention or eliminating the risk.

MR. FINFINGER: Thank you, Kobus.

This question is for Cathy Kowalski. Is it possible that the ability of a rescue chamber could negatively effect the miner's willingness to evacuate through small conditions given the uncertainty of it later?

MS. KOWALSKI-TRAKOFLER: I heard part of that. Is it possible that the?

MR. FINFINGER: Is it possible that the availability of a rescue chamber could negatively effect the miner's willingness to evacuate through small conditions given the uncertainty of it later?

MS. KOWALSKI-TRAKOFLER: That's a very interesting question. We do not have a lot of data on sheltering. The normal human response, which comes from data on escape from structural fires, is to egress, get out, and usually there are several parameters on that.

People tend to affiliate and leave with groups, usually the groups they came in with, and the tendency is to leave the same way they came in.

Sheltering and training miners to go into shelters is the -- the training aspect is absolutely key because the natural tendency is to escape.

Did that answer the question?

MR. FINFINGER: Dr. Oberholzer.

MR. OBERHOLZER: Mr. Chairman, I would just like to add something here. In Queensland at the moment, if it is directed so strongly at escaping, that we have now just developed what we would call a mine rescue vehicle, which is a diesel vehicle that's fitted with sensors that will allow a person to get out of the mine without actually seeing the roadway that he is traveling in. It wasn't part of the scope that I was asked to talk about, but this information, if anybody out there would like to know more about it, it's available, and they can contact either contact me here or later and we can discuss the matter further.

MR. FINFINGER: Thanks.

MR. KRAVITZ: That brings up a -- you just ran into this next question I had in my hand, and it's an interesting question. How should we address the handicapped people, physical disabilities, overweight, aging miners when we require walking or crawling escape routes? Should vehicles be developed for these people?

MR. OBERHOLZER: This whole vehicle issue was developed on an exercise at the Castro mine where the exercise actually showed the difficulties that people or brigadesmen would have when you go into the 2 kilometer plus panels, and actually they are not able to reach it with the oxygen that they've got on it, and we came to the conclusion that there must be a better way, a faster way to get people that are incapacitated out of the mine.

If anybody is interested, all this is written up under ACOR project. It's available. You can acquire this, and if anybody would like to write me, I'm sure I can supply them with the latest information.

MR. FINFINGER: Thank you.

MS. KOWALSKI-TRAKOFLER: I would just like to add something to that. I would think there is also a self-selection aspect of that.

Mining is dangerous. Miners know the environment, and if they can't egress, if they can't get out in danger, I would suggest that in many instances they are going to self-select themselves out of the workforce.

MR. FINFINGER: Thank you.

Next question is about self-rescue devices. What work is being done on self-rescues to replace the current goggles, mouth piece, note clip arrangement with a full face piece arrangement?

MR. KOVAC: None. If you have a face piece, you have to be fitted. No, if you have a face piece, you have to be fitted to that face piece. A self-rescuer becomes yours. If you have facial hair, you have to shave it in order that that face piece could be easily fit in an easily accessible package. We've added size, weight, complexity to the program, and as desirable as it might seem, mouth piece, nose clip is a better way to go.

And since you deploy multiple rescuers in mines along the escape ways, those face pieces would have to be yours. Whether you would keep them and interface with the device or not, it would still have to be your face piece.

MR. KRAVITZ: Thank you.

This one is for Mr. Van Zyl. You used computer simulations as a tool for landscape planning, and the second question, and this is do you use some tool for miners training? The first one was computer simulation for mine emergencies, and the second one was tool for miners training.

MR. VAN ZYL: As far as my knowledge goes, we haven't used any computer-based simulation to determine the positioning of self-rescue bays. On the computer-based training, we did start off with virtual reality training for the workforce, but having a workforce that's been dominantly illiterate, we found that your virtual reality training had to be very, very realistic to use abstract forms and colors. If you didn't represent exactly what was underground, the connection was very difficult. They made the connection between reality and the training on the computer-based was not really brought across, so that program ended about five-six years ago, but we have started looking at advancements in computer simulation and obviously the increased power of computers. But currently we're not using it.

MR. FINFINGER: Thank you.

The next question is for Dr. Jon Oberholzer. I would like to know your opinion about additional strategically located bore holes along intake entries which could serve as escape openings equipped with rescue hoist capsules.

MR. OBERHOLZER: The placement of bore holes ultimately would be an economic decision. I'm not sure this is going to answer it rightly. In a country where you have got mines that are 150 meters deep, going down with a bore hole is not expensive. If you are sitting, from what I hear in West Virginia where you can go down a thousand feet to get a seam, it's going to get very expensive. Then it's going to be very difficult to do it.

The other thing that I would like to add is if I look at what is being offered in the form of refuge bays at the moment, one starts wondering why one wants to take the effort to go very deep with a bore hole very deep in a situation where it becomes almost uneconomical.

So I don't know if that answers the question.

MR. KRAVITZ: Is that because of the available oxygen sources that you can actually build into the --

MR. OBERHOLZER: Well, if I just looked at all the products that were offered this afternoon that would supply oxygen, keep people there for 90 hours, 120 hours, one sits and considers why would you try and drill a 1,000-foot bore hole to supply air.

MR. KRAVITZ: Okay. Anyone else want to try that?

MR. FINFINGER: Okay, next question is for Kubos Van Zyl. You spoke of using oxygen candles inside underground shelters. How do you prevent carbon monoxide from entering into the chamber form a contaminated mine atmosphere?

MR. VAN ZYL: Oxygen candles is currently used in both the limited products available in portable units, and also in the fixed chambers. In the portable units, there is CO scrubbers that's installed as part of the unit, and on the fixed units, as far as my knowledge goes, it's actually on positive pressures. You release the oxygen and that's just bled into the environment, and if your environment needs more oxygen, you just light another oxygen candle. So there is a difference between the two, the application of the two.

MR. FINFINGER: Thank you.

MR. KRAVITZ: Okay. This one, if the panel doesn't feel they can address this, we can ask the manufacturers if they are interested in addressing it, but this one, I think the question was written before the manufacturers got up here. With all the safety chambers presented, none of them seem to have significant blast or fire rating. None seem to insulate the occupants from extreme heat.

Would any manufacturer like to address that? Okay, the microphone is up here.

MR. RAU: With the explosive proof, did they mention that? They're interested in explosive or just fire rating?

MR. KRAVITZ: Both.

MR. RAU: With the explosive proof, I don't think anything is going to withstand a 80 psi, which people are throwing around. It's an enormous force, and if we did make them and manufacture them to withstand that, at the end of the day they would be thrown out at the end of the drive.

The way we see it the refuge chambers are basically there to substitute for barricading. Now, we can manufacture them to be explosive proof, fire rated. There is no limit to what we can do. We actually have a refuge chamber in Sweden which is on a locomotive and it drives itself out of the tunnel and it has heat sensoring cameras on it. So there is no limits. It's got 15 beds, the frig., almost the kitchen sink chucked in. So there is just no limit. It's just who is going to pay for it, and what we want to do with it.

Does that answer it?

MR. KRAVITZ: I think so.

Any other manufacturer want to address that?

Okay, I want to do a follow-up question. Is Randy still here? Yes, there he is.

If you build a bulkhead type of shelter into a pillar, how would a fire and explosion affect that?

MR. BERRY: I'm glad you called my name because I want to address a couple of things on that.

First of all, and I have to apologize because it was a long time ago, and there was one document that I wasn't able to lay my hands on, but I have a problem with my friend, was it Kelvin, who mentioned 80 psi. I'm not so sure that's the right number.

That was not the number -- I know that was not the number that we designed to, and as I say, we had three bulkheads and all survived actual underground explosions.

Part of the reason for putting bulkheads in crosscuts, as I outlined, was to get it out of the direct line of fire so to speak. That should largely eliminate the collateral damage that's caused by not just the shockwave, but the debris, locomotives or whatever getting carried down entries.

So you've got a couple of different things going. You've got pressure waves and you've also got debris being carried.

But I wouldn't go to the bank with that 80 psi number. To me, that's high.

MR. RAU: Even 80 psi for portable rescue chambers in --

MR. BERRY: That's what ours was designed to if my memory is right. I think we designed it to, and this is really 30-year-old memory, so I apologize, but I think we designed it for somewhere between a 9 and 15 psi, but that was not a static load. Okay, that's a dynamic load. So to convert that to static you effectively -- let me finish -- you effectively double it.

Okay, so we had somewhere between basically a static 20 and 30 psi. That's consistent, by the way, with a Canadian report, and where else did I see? Something on the order of 14 bar, which I think works out to -- help me, English people -- 20 psi?

MR. BROWN: -- force people inside. It's not a matter of the structure itself, we're saying, it's the blast to minimize the force of the people on the other side. Eight psi would knock somebody out, down, down, that's it, they are done.

MR. BERRY: Yes.

MR. FINFINGER: Next contribution from here maybe.

MR. GRACIOLI: Ken Gracioli with KEM BioShelter. We've been working with the West Virginia task force on the issue of mine safety. One of the questions that they sent us in writing was how did your shelter protect against 26 psi, and they said that above that level there is no sense in protecting because the human body can't withstand it.

MR. BERRY: All right. So once again I' hearing with the exception of the one presentation --

VOICE: I would agree those are the numbers?

MR. BERRY: What's that, John?

VOICE: Those were the numbers, 20-30 psi.

MR. BERRY: Okay, sounds like we are pretty unanimous on that, and you can very definitely build bulkheads in chambers to resist that that I don't think are too overwhelming. I showed you three examples.

Anything else?

VOICE: Have you considered in that study the positive and negative issues when you do an exploding, a blasting situation?

MR. BERRY: Actually, my talk could have gone on for hours. As a matter of fact, in one of the designs, okay, the second design I showed that was supported from the top and the bottom, but down into the floor, okay, so there was very little support at the roof, and in fact we were worried about it upsetting, okay, the other way, and I left that out because it would have just taken too long, but it is pinned into the roof to prevent it from upsetting on the back swing, so to speak. That was a good question.

MR. KRAVITZ: Would you like to respond to that then?

MR. WU: Yes, I would like to respond on that particular.

We were thinking about using what it appears we need, as I stated, we want also to take care of this one not only for the exposure purpose and also the water. Now, that was not being thought in the past. In these last 15-20 years many things have happened. So when people cannot get out, then you get into that areas of want to be able to hold in that water, and that water is combined into one of the things we're talking about for that pressure, aesthetic pressures.

Now, the other things we're talking about is on grouting curvage on the roof, on the coal mesh materials. When you're doing ground curving on those to prevent the passage, those would need more work to be done. That's probably the things we need to strengthen that from footing and rib and roof. There is a lot of other problems that we haven't talked about.

MR. FINFINGER: Okay, thank, Kevin.

We would like to go on to the next question. This is for Joel Kovac. How will we address the storage and transportational self-rescues with the manufacturer's recommendations? For example, exposure to 32 degree Fahrenheit.

MR. KOVAC: You follow the manufacturer's recommendations in order to keep the device within its service life plan and to keep it in approved condition.

The 32 degrees represents storage. Don't store it at that temperature. You monitor that. If you exceed the manufacturer's instructions, remove the device from service, replace it with a new one.

MR. KRAVITZ: Okay. This one to the panel, and if the panel would like to defer to the audience we can do that. Should we encourage mine designers, engineers to design mines with escape shaft entries with shorter routes to the surface? Anyone?

MR. VAN ZYL: It always comes down to cost. For an example, in deep South African --

MR. FINFINGER: Put the microphone up to your --

MR. VAN ZYL: I'll go to the microphone.

I said it's always an issue of cost. For example, in deep South African gold mines the original mining layout was to get to the ore most effectively and safely currently due to heat loads. Mine designers are seriously taking into consideration ventilation requirements when actually doing the mining, the mining layouts.

So again, if it gets to the point where you have multiple fatalities, potentially can be brought into the design criteria. But again, it's open for debate.

MR. GRYSKA: What I would like to do is talk about what we do in Ontario. There is legislative requirements in Ontario to have a second means of egress. So in fact we do have a second escape way and it's mandated by legislation. But mind you again, we don't have coal mines.

MR. FINFINGER: Okay, thank you.

Next question, doesn't having a stove in the refuge station present an explosion hazard? A stove.

MR. VAN ZYL: Depends if the mine is classified as a fire mine or non-firing mine. If it's a firing mine, definitely. I don't know a flame proof or intrinsically safe stove, but again it depends on the -- well, in South Africa it will depend on the classification of the mine.

MR. KRAVITZ: Same thing holds true for electricity like microwaves and refrigerators.

MR. VAN ZYL: Exactly.

MR. KRAVITZ: I think some of the things -- most refuge chambers we saw pictures of that were actually mental/nonmetal mines, and it really didn't apply to the coal situation.

Probably you want to put MREs with the heatable, open it up and heat the other, you know, that's another question about the MREs, would that do anything.

Okay, I don't know if anyone knows the answer to this one. You know, we would have to dig into our databases, but how much caches are there today in all coal mines? Are mines required to report the number of caches?

Anybody want to take off? Is Terry there, Terry Bentley?

I know that coal, you know, has plans for all caches currently, and the cache storage plans, and I'm sure that all those are reported back into the system, but I've never seen a report, and maybe someone from coal, anyone here want to answer that one?

Okay. We will see if we can get an answer for you. If you could come up and identify yourself on this card, we'll definitely get an answer for you, okay?

MR. FINFINGER: Okay. If a sustainable IE nonventing liquid air supply could be developed for rescue chambers, would be beneficial to have an air supply of greater than 5 days. If more than five days, what quantity is desirable?

MR. KRAVITZ: Interesting question. How many days would you actually prepare for? Anyone want to take a stab? One day more than you need, right?

(Laughter.)

MR. KRAVITZ: That seems like it would be a real hypothetical there.

Has any work been done on infrared imaging to penetrate smoke? I think we saw in one example. Bud Meyer was showing a face piece with -- and Chuck was showing the IRs too, I know he's been working on that.

That's all the written questions. I think we have time for some questions from the audience. If anyone wants to ask a question, please come to the microphone, identify yourself, and then if you have someone you want to ask the question of, please do so.

MR. PAPEO: Christopher Papeo from NexTec Materials in Columbus, Ohio.

The question is probably for Dr. Oberholzer or perhaps Mr. Van Zyl. We have the capability in NexTec materials to make oxygen from water by a kind of reverse fuel cell technology, so we don't have to bring any compressed air tanks or oxygen tanks into the coal mines since coal and methane are explosive with air and oxygen.

I'm thinking that this would be a great advantage for perhaps in rescue chambers as a way of bringing in oxygen and air, and you know, if air/oxygen compressed tanks get ruptured from one of these explosions we've just been talking about, 20 psi explosion or so, they could add to the problem in the emergency.

So I'm wondering from your experience, or it could be anybody but I'm just kind of curious what Mr. Oberholzer would say, if that could be a great advantage to be able to generate oxygen that way on demand as opposed to having a storage of oxygen.

MR. OBERHOLZER: I would think that in a portable cell or refuge bay the ability to have oxygen would be very advantageous on one condition. I don't think the generating facility must actually take up too much space.

One thing as I pointed out previously it is quite evident, if we look at all the products in offer and the new technology that is available, that I think the whole original theory of piping a down bay and only using candles, well, that is passe nowadays. I think there is new technology that is going to overtake us and bring a whole new, I would say a new generation of refuge bays that possibly I might even not know about to the fore.

This is a typical type of thing as in my talk I pointed out that there are certain inputs from the environment that create or stimulate the growth of things. Failure is going to create the growth of a new generation of things out there that the mining people can -- for some it's going to be easy, for some it's going to be difficult, but the new products are going to be there.

I hope that answers the question.

MR. PAPEO: That was helpful. Thank you.

MR. MCKENNA: Tom McKenna with Micropore, Inc., a manufacturer of CO2 absorbants, and I guess I had a couple of comments and maybe a question relative to acceptable CO2 levels within some of the shelter scenarios.

I know the U.S. Navy in their submarine has approved our product for use and is able to supply seven days of life support at a 3 percent maximum CO2 level. NATO submarine fleets have also accepted levels at 2.5 percent. I saw a couple of levels that were down around the 1 percent for the mine safety shelters.

I guess, you know, in the diving community and submarine safety community we have seen that you can support life -- life support is acceptable up to exposures of 3 percent for up to 40 days without any physiological effect, and I guess we would recommended that NIOSH and MSHA set a level that's somewhere in that 3 percent range.

I know that with the re-breathers and SCSRs half percent to 1 percent seems to be the accepted level, and that's great for working environments, but with an emergency safety shelter situation, higher levels are probably acceptable.

So I guess the closing question is what is the intent for acceptable CO2 levels within the safety shelters?

MR. KOVAC: If you regard a refuge chamber as a respirator, closed-circuit respirator for a lot of people, there are standards for certifying the same, or stipulated what the performance has to be over a required time period. So you are right to raise those issues. The 2 or 3 percent, I wouldn't see that as a problem. It would make it technically easier to achieve.

But again, there are no standards. And so when people make claims about the performance of those chambers, those are claims that need to be verified, and it's best to do that in as scientifically sound manner as possible. So if we're not talking standards, we're at least talking about somehow making sure that the chambers do what we intend them to do, but that remains to be seen.

We all have to reach some common agreement, what safe life support capacity is, what sedentary oxygen rates/consumption are, are the people in the 1983 report I had done, are people really going to be sedentary, aren't they going to be managing the functions of the chamber. They are going to be moving about. Somebody is going to have to attend to or monitor the oxygen generator. There is going to be other things to be dealt with. So to project a flat three-tenths of a liter uptake per minute of oxygen or half a liter per minute of uptake, that may be wrong. You might have to have fluctuations.

So there are issues like that that have to be dealt with, but primarily what's a safe level, how do you verify it, how do you verify what the claims are for these chambers, or what ought they to be, what performance should we stipulate.

MR. MCKENNA: Thanks.

MR. PINKLEY: Jim Pinkley. I'm the market manager for Hilte Mining, 13-year underground experienced miner, mine manager, degreed engineer.

One of the questions I have is to Alex. It seems that sealing seems to be a big issue with the refuge chambers and use of the chambers in Ontario in practical terms. In regards to that, you know, there is a lot of concern over explosions and what is going to happen with the chambers and so forth, but I'm not seeing an interest in having materials for the miners when they escape to the chamber.

If there is damage to these chambers, if they are going to be able to do anything to be able to fix that. That sealing doesn't seem to be on the radar screen for us here in the U.S. while it's been the top five important issues for Ontario, and I would like for Alex to comment on his practical experience, and then I would like to hear from dr. Rau and some of the other personnel here within the U.S. on where we are at with sealing. Go ahead, Alex.

MR. GRYSKA: Okay. By the sealing, you're referring to the sealing the door closure, is that correct, or --

MR. PINKLEY: Yes, and having materials to seal with.

MR. GRYSKA: Yes, okay.

MR. PINKLEY: I mean, you know, we have seen a lot of the manufacturers put up their information, but I don't see how if there is damage to the -- if there is damage to the facility, how the miners have any recourse here, you know, and you're all talking about, you know, 20 psi, 30 psi, debris waves. You know, in real life let's face reality. Things are going to happen.

MR. GRYSKA: Yes. Okay. During my talk, I did mention to you the hazards that our mines are exposed to are very different than that of the coal mine environment. Certainly the occurrence of methane is very rare in our mines. Secondly, one of the other hazards is we do get sulfide dust explosions.

Our experience has been is when we do have something of that serious nature, knock on wood, it hasn't happened very often. We had in the mid-eighties a situation whereby we had a sulfide dust explosion. There were only three miners underground, and two of them were fatally injured, a third one survived. They didn't even have an opportunity to go to the refuge station.

MR. PINKLEY: I guess my question is more in the fact that when your miner is trying to go to that refuge station, do they not use the sealing materials to seal themselves in?

MR. GRYSKA: Yes. Absolutely. Yes.

MR. PINKLEY: That's exactly what my point is.

MR. GRYSKA: Oh, yes.

MR. PINKLEY: We're not making any preparations to allow the miners here to have that option in case there is any type of damage, and I just think we are overlooking some key issues here.

MR. GRYSKA: One of the things that we do focus a lot on in Ontario is training, training our miner rescue teams, training our miners as far as refuge stations. As mentioned to you, we do have fire drills and we do run simulations, and in some of those circumstances they will go as far as sealing themselves into the refuge station to make sure they are functioning properly.

MR. KOVAC: I would like to make a comment too. One of the reasons that you would evacuate a refuge chamber is that you were incapacitated, you're injured, things are going against you. To make the assumption that everyone in that chamber will be fit, will survive that experience is short-sighted.

When you look at the report we did in '83, one of the requirements was to include body bags. The ability to handle casualties, to handle fatalities, and do it with a manner and decency and everything like that.

Refuge chambers are very hard to deal with. What has to be in them, how you train people to deal with going into them, what you expect those people to do while they are inside, how they will react to tragedies, but you need to begin considering things like body bags, the ability of the miner to repair the miners who are so in shelter to repair that shelter in the event that there is damage, bring it back up to gas-tight condition whenever it's sealed. All those things have to be factored in.

MR. KRAVITZ: Excellent point. Kevin has a comment to make.

MR. WU: I want to answer that question. I was trying to talk before that question could be raised. In all the years we're talking about the barricades --

MR. KRAVITZ: Lower that microphone a little bit for you, sir.

MR. WU: In a mining emergency conditions for a miner to be able to barricades and never could build ones which to serve its purpose. It's very difficult. So the important things, you know, everybody agreed, the aims is you've got to have some kind of refuge chambers for the last choice. So hopefully again design, no damage.

Now, grooves you 100 percent, you needed some materials, whatever that needed to be discussed to finalize what needed to be there be put into use. That should have been no argument. When you say hopefully you're going to design something that would not be damaged the first thing, because when you have an emergency like this if something happens, it's always difficult, always difficult, and all the barricades through the years you can never build it in a short period of time, and to serve its purpose.

MR. KRAVITZ: Okay, we have time for one more question. That's the last one. Fortunate you are.

MR. RAU: Just quickly wanted to make the point the difference between a sealed environment and a leaking environment. Two completely separate systems. In a sealed environment you have to scrub the atmosphere. In a leaking environment you have to ensure that everything that goes into that chamber must come out, so that's a compressed air style system. You cannot use oxygen-generating tools in a leaking environment. It doesn't work. You have to scrub the oxygen, otherwise the carbon dioxide builds up, so there is succinct difference in between the two systems. I think that's just something that's been missed.

MR. KRAVITZ: Kathy, you were about to tackle the microphone, so you better ask a question.

MS. SNYDER: Kathy Snyder, Mine Safety & Health News. Basic question. I think we have heard at least one coal mine, if I remember correctly, make a decision to use refuge chambers. I understand it's a difficult thing in coal mines because you can have different scenarios. You could have a second explosion. You could have an engulfing and overwhelming fire, but then again you might not in a coal mine have those things happen.

And I was wondering if anyone has any information on the decision process that one or mine operators in coal may have gone through deciding to use these chambers or not use these chambers.

MR. KRAVITZ: Anyone?

MS. SNYDER: No baseline.

MR. BROWN: No baseline so there is not --

MS. SNYDER: Right.

MR. BROWN: I'm shocked. Quite frankly, I'm shocked. I'm not in this business. So how do you arrive at what you require if you don't know what needs to be --

MS. SNYDER: Did someone say there was a New Zealand mine in coal that --

MR. RAU: In Australia, all our mines have to be treated with that. Essentially you couldn't put that unit into the coal mine. In New Zealand, same as the U.S.

MS. SNYDER: Do you know how they decided that this was a good thing to do even though it was a coal mine and there were some possible scenarios where it might be worse than -- you might be worse off?

MR. RAU: (Not on microphone.) I guess it's just an area in the mine which I saw that it wouldn't address that successfully. It's one single chamber, it's not the whole mine.

MS. SNYDER: Thanks.

MR. KRAVITZ: And one last, last question.

MR. LONG: Yes, I want to talk about that also. I'm Gary Long from BHPBilliton, New Mexico, San Juan

Underground, and we decided in January that we were going to do the right thing and build some refuge chambers and beings we are an Australian-owned company we had plenty of information of how to build those, what to put in them, doing risk assessments, that type of thing, and we done some testing with rescuers at our mine, it's about a six -- well, not even a 6 percent decline.

We done some testing with the CSE100s, and determined that we were going to put rescue chambers or refuge chambers we call them every five to six thousand feet. On the testing we done, we were able to -- one 6,400-foot walk and another person 7,400-foot, so we just went with the five to six to keep our refuge chambers far enough apart that you could actually walk, get in fresh air, we've got more bore holes to each one, getting fresh air to change rescuers and keep moving. And then if egress is stopped, then we could use those chambers to stay in, and they have everything that we've seen here today. They have everything plus that.

MR. BROWN: Looking at anticipation that distance, so -- (not on microphone.)

MR. LONG: Yes, that's basically it, is that every 5,000 feet, we know we can make it that far. If not, we'll stop, and every panel has two of them. The way things are going we've got 1,250-foot panels, and we're making a lot of assumptions doing this but we thought it was the right thing to do psychologically for the coal miners also. They have another opportunity there if something should happen, so I think psychologically the miners are more of these by having such another instrument, and I think it's the right thing to do.

MR. KRAVITZ: Okay, thank you very much.

I think we have accomplished our mission today, stimulated thought, and we have identified quite a few things for a research agenda, and I would like to thank all of you for coming today, but be sure to pick up the attendance list. Thank you. It's been a pleasure working with you. Thank you, panel.

(Applause.)

(Whereupon, at 5:34 p.m., the workshop was concluded.)

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REPORTER'S CERTIFICATE

DOCKET NO.: None

CASE TITLE: Mine Escape Planning Workshop

HEARING DATE: April 18, 2006

LOCATION: Washington, D.C.

I hereby certify that the proceedings and evidence are contained fully and accurately on the tapes and notes reported by me at the hearing in the above case before the Department of Labor.

Date: April 18, 2006

Christina Chesley
Official Reporter
Heritage Reporting Corporation
Suite 600
1220 L Street, N.W.
Washington, D.C. 20005-4018

DOCUMENT 15

19950

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PORTABLE REFUGE CHAMBER PROJECT

STAGE 1 REPORT

TO

JOINT COAL BOARD HEALTH & SAFETY TRUST

BY

MINE SITE TECHNOLOGIES PTY LIMITED

DECEMBER 1994

1. OBJECTIVE:

The objective of Stage 1 was to refine the basic specifications of the Portable Refuge Chamber (PRC) for application in coal mines. The specifications were determined by a series of meetings conducted by Mine Site Technologies' personnel and Mining Union representatives, Mines Rescue personnel, Mine Operators, and designer (Fink International) and manufacturer (Cowan Manufacturing).

The results of this will allow Stage 2 and Stage 3 to commence the detailed design and manufacture of the working prototype.

2. RESULTS:

Stage 1 refined the PRC concept to suit coal mine conditions through a series of meetings and site visits involving the groups mentioned above. A summary of the key steps and meetings results include:

September 1994:

Following three months of initial study and general discussions with mining personnel the concept of a PRC was confirmed as feasible and worth pursuing. During September key events were:

- Determine preliminary PRC design with Fink International and Cowan Manufacturing. Drawings and specifications for an initial device were produced to allow more detailed presentation to mining groups.

- Presentation to Power Coal representatives (including Dick Wilkinson, Bob Clifton) confirming support for the concept. It was also confirmed that due to the new concept of refuge bays/chambers to the coal industry that early input from mine workers (i.e. the mining unions) would be extremely valuable.

- Presentation of the PRC concept and Mine Site Technologies' capabilities to CFMEU (Tony Wilks).

October 1994:

Key events were:

- Meetings were arranged between all parties in Newcastle to go through the various design and application issues. Groups represented were Mines Rescue (Gary Gibson, Murray Bird); CFMEU (Tony Wilks, Matt Best, Jack Tapp); Powercoal; Cowan Manufacturing; Fink International; Mine Site Technologies (Gary Zamel, Greg Payne, Tony Napier).

  Key points raised in the meeting and subsequently acted on included:

  * Physical Size needs careful consideration to allow access to underground workings. Should be less than 1.8 metres in height and less than 2.2 metres wide. The length should be such that it could be transported in an Eimco Bucket or towed.

  * Dual function capability, i.e. Refuge Chamber and sterile First Aid Room.

  * Consider strong glands/sockets for access to external air, power and communications.

  * Designers and manufacturers need to visit underground coal mine.

  Basically, this meeting refined the concept and identified areas requiring further assessment. It was recommended a submission be made to the JCB Health & Safety Trust to allow detailed specification, design and manufacture to proceed.

- Underground visit by designer (Fink International), manufacturer (Cowan), and Mine Site Technologies personnel was undertaken at Cooranbong Colliery. This included discussions with mine undermanagers and work force. The visit gave Fink and Cowan an appreciation of the environment that the unit must fit and work in.

November 1994:

Further discussions with mining groups were held and the initial design altered to take into account information received to date: Key events included:

- Preliminary drawings and specifications modified and documented.

- Preparation of JCB application and its submission.

- Discussions with mine industry personnel, including:

    * Inspectorate (Bruce McKensey in NSW and Brian Lynne in Qld).
    * Appin Colliery personnel (Bernie Gray-Spence)
    * Tahmoor Colliery (Bob Miller)
    * Ellalong Colliery (Brian McGowan)
    * North Goonyella Colliery(Tony Muguira)
    * West Cliff Colliery (Greg Niewenhuis)

    These various discussions confirmed the acceptance of the PRC concept as worthy of progression.

December 1994:

Key events included:

- Acceptance of submission to JCB for funding support, beginning with Stage 1.

- Meeting with Newcastle Mines Rescue Station personnel (Murray Bird) to discuss project to date. Inspection of the underground gallery at Newcastle Mine Rescue Station was carried out to ensure the prototype PRC can be installed. It was confirmed that keeping the height below 2 metres was essential (actual size is 1.76 metres). Along with proposed width and length dimensions it was determined access was good and two potential installation sites identified.

The results of Stage 1 work, as outlined above, can be summarised by defining the PRC unit as follows:

Basic functional criteria are:

- Essential to provide a fully self contained clean air environment that can be maintained for a minimum of **twelve hours for eight men** by use of air cylinders and CO_2 scrubbers within the chamber.
- Provision for valves to allow compressed air supply, if available, to be accessed.
- Power supplied by mains power with internal backup supply.
- Lighting through overhead light with backup through miner's cap lamps and cylume light sticks.
- Telephone access and other communication devices available at the mine.
- Toilet with a holding tank.
- Access via hatchway at one end through an air lock.
- First aid kit and stretcher.
- Fresh water and glucose to maintain occupants energy levels.
- Fire extinguisher.
- Siren, flashing light and reflective markings to assist locating chamber by personnel seeking refuge and rescue teams.
- Tow hooks rings and seat belts for occupants.

The area of particular importance in actual using the PRC in a coal mine is its physical dimensions.

Physical Criteria include:

- Accommodate eight people but have outside dimensions suitable for installation in a typical coal mine. For this project a size that will also allow installation into the underground galleries at the Newcastle Mines Rescue was required. further meetings and discussions with Newcastle Mines rescue superintendent confirmed the appropriate size to be outside dimensions of **1,760mm high x 1,900mm wide x 3,260mm long.**

- Suitable to be picked up in a LHD bucket or dragged on skids.

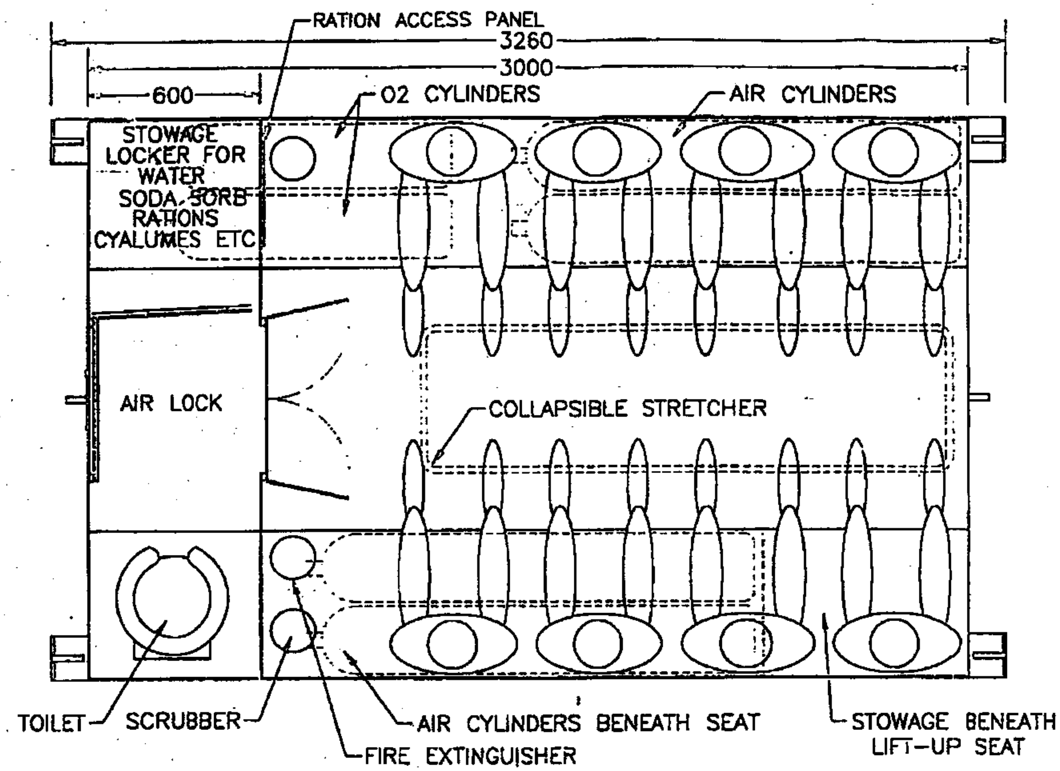
See **Figure 1** showing the dimensions and general layout in more detail.

3. CONCLUSIONS AND RECOMMENDATIONS

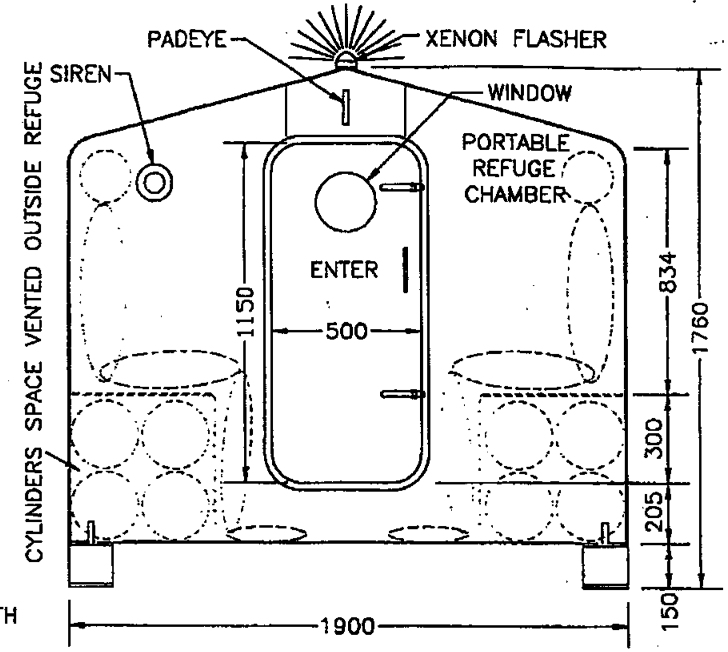
The results of Stage 1, basically a review and refinement of previous work, have confirmed the PRC concept as viable. A prototype PRC could be designed and constructed to meet the requirements identified in our objectives.

Mine Site Technologies, and others associated with the project, remain convinced that the Portable Refuge Chamber offers the coal mining industry an important safety technology.

This and results of Stage 1 give us confidence to recommend Stage 2 and Stage 3 be commenced to allow a working prototype to be produced as quickly as possible.



SIDE ELEVATION



END VIEW

SPECIFICATION

REFUGE CAPACITY	8 OCCUPANTS
WEIGHT WITHOUT OCCUPANTS	2100 KGS
WEIGHT WITH OCCUPANTS	2700 KGS
DIMENSIONS	3260 L X 1900 W X 1760 H
INTERNAL VOLUME	6.5 SCM
DOORWAY	500 W X 1150 H
SELF CONTAINED LIFE SUPPORT DURATION	12 HRS.
LIFE SUPPORT OUTFITTING	
'G' SIZE AIR CYLINDERS	8 X 6.4 SCM
AIR DRIVEN VENTURI SCRUBBERS	2 X 7LPM FLOW
'E' SIZE OXYGEN CYLINDERS	2 X 3.8 SCM
FRESH WATER STORAGE	16 LITRES
SODASORB STORAGE	40 KGS.
TOILET	BUILT IN

SPECIFICATION

OXYGEN ANALYSER	TELEDYNE 354
CO2 ANALYSER	DRAGER TUBES
INTERNAL LIGHT SOURCE	6 X CYALUME LIGHTSTICKS
STRETCHER	500 X 1800 FOLD-UP
FLOORPLATE	TREADPLATE
MATERIAL	MILD STEEL, INORGANICALLY ZINC PRIMED
FIRE EXTINGUISHER	WORMALD
LOCATING DEVICES	SIREN, XENON STROBE
COMMUNICATIONS	VIA WATERPROOF CONNECTION
NUMBER SEATBELTS WITH HARNESSES	8
RATIONS	OPTIONAL
PRESSURE RATING	NIL
REMOVABLE PNEUMATIC WHEELS	OPTIONAL
COLOUR	WHITE GLOSS

"STRICTLY CONFIDENTIAL"
PROPERTY OF MINE SITE TECHNOLOGIES PTY LTD

FIGURE 1

CLIENT: MINE SITE TECHNOLOGIES
MANUFACTURED BY: COWAN MANUFACTURING PTY LTD
DESIGN BY: FINK INTERNATIONAL PTY LTD
TITLE: 8 MAN PORTABLE REFUGE CHAMBER
DRAWN: ERIC FINK | CHECKED | APPROVED
DATE: 14/10/94 | SCALE: N.T.S.
DRAWING NO.: M-10-001 | SHT 1 | OF 1 | REV A | SIZE A3
WEIGHT OF ASSEMBLY: –
TOLERANCES: – 0.X ∠ ±0.25 ±0.13 ±1°

REV	DATE	DESCRIPTION	
A	20/12/94	WIDENED & LOWERED REFUGE	E.G.F.

DOCUMENT 16

PORTABLE REFUGE CHAMBERS : AID OR TOMB IN UNDERGROUND ESCAPE STRATEGIES

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ABSTRACT

A safe breathable atmosphere is of prime importance in order to support and sustain human life during the occupation of portable refuge chambers. If a satisfactory atmosphere is not assured, portable refuge chambers have a very limited occupancy time and a "tomb" effect is created in a very short period of time.

A well designed, constructed and located portable refuge chamber could however enhance the survival potential of workers unable to effect self escape, whilst awaiting aided rescue after an underground incident.

The need to maintain a breathable and healthy atmosphere thus necessitates the control of the physical environment which entails an applicable source for the replenishment of oxygen, a scrubbing system for the removal of metabolically produced carbon dioxide and the cooling and drying of the ambient air.

This paper gives a brief description of the newly developed Survivair Reclaimable Refuge Chamber (Survivair-RRC) technology demonstrator. Breathable air is provided by means of the Survivair-E concept. This concept combines two integrated systems, viz. the replenishment of oxygen by means of solid state oxygen generating units and the removal of metabolically produced carbon dioxide with the aid of a soda lime scrubber system. A dual

custom built environmental control system maintains a suitable temperature and an acceptable relative humidity within the refuge chamber.

The results of an evaluation test verify the ability of the Survivair-RRC to support 12 workers for up to 24 hours. During the test both oxygen and carbon dioxide concentrations were maintained at safe levels whilst comfortable environmental temperatures and humidity prevailed. The results proved that this concept can be considered as an alternative to the installation of permanent refuge chambers.

1. INTRODUCTION

A refuge bay or chamber is an underground shelter, designed to protect miners from the bi-products of a fire, limited explosion or other incidents. Its purpose is to enhance the potential for aided rescue of miners after an underground incident if they are not able to effect self escape. It thus provides a secondary survival capability in the event that all other avenues of escape are blocked.

Circumstances which support a role for refuge chambers as a component of an aided rescue strategy for a mine are :

- situations where there is significant risk of entrapment;
- when miners are unable to effect self-escape;
- when mining in an area remote from the normal access routes into the mine, or
- where the time taken for people to evacuate via normal access routes may be excessive.

The concept of refuge chambers dates at least from the 1930's. It is generally accepted that the idea originated with the practice of entrapped miners barricading themselves in a good air region in order to separate themselves from a region of fire and smoke.[1]

Following the disaster on the 10th February 1928 at the Hollinger Consolidated Gold mine in Timmins, Ontario where 39 miners died after an underground fire[2], the Mining Act of Ontario was amended to include provisions for refuge chambers where the chief inspector deemed necessary.[3]

After the Kinross mine disaster in 1986, the Government Mining Engineer decreed the compulsory installation of refuge chambers for all mines in South Africa. This was legislated in 1987 through South Africa's Minerals Act no. 27 of 1956, regulation 24.20.2.[4]

Since then, the provision of refuge bays or chambers became a widely accepted practice in South African mines and they generally form an integral part of escape and rescue strategies. In these strategies refuge bays and chambers serve as places of safety, i.e. target destinations for escape during underground incidents and as logical focal points at which ensuing rescue operations can be directed.[5]

The cost of equipping and maintaining a permanent refuge bay could be considerable. The current trend is to locate refuge bays closer to the workface, in accordance with the maximum safe travelling distance which can be covered with the aid of self-contained self-rescuers. The introduction of continuous miners with a high advance rate in collieries, has also increased the frequency of refuge bay installation. Where the surface land is used for agricultural purposes, or when the mining activity is beneath mountainous terrain, marshland or a water mass the practical implications of supplying a borehole to a refuge bay at a colliery, are not always feasible.

Because of the consequent limited lifespan of permanent refuge bays in collieries, the use of portable refuge chambers can be an alternative to the establishment of permanent refuge bays. A portable refuge chamber properly located and well designed and built to protect and support workers for an extended period of time, could enhance the chances of survival of workers unable to effect self escape.

2. PORTABLE REFUGE CHAMBERS

One of the first portable refuge chambers built, was the Dräger Escape Chamber used at the Konrad mine in West Germany.[6] This completely self-sustaining escape chamber affords protection for six workers for at least four hours. A positive-pressure facility prevents the ingress of gas and smoke into the chamber. The air supply is via compressed air carried with the system, whilst the metabolically produced carbon dioxide is bonded. The ambient air in this chamber is cooled and dried.

The portable refuge chambers which are currently available and used in South Africa, lack total environmental control and have a restricted occupation time. This restriction is derived from environmental constraints such as the uncontrolled rise in temperature and relative humidity due to the normal metabolic activity of the occupants, and an inadequate supply of breathable air.

The maximum occupancy time of a portable refuge chamber without air supply is considered to be the time from the start of occupancy until an upper limit of 3% carbon dioxide and a lower limit of 16% oxygen is reached. Because of the size limitations, portable refuge chambers usually afford its occupants each an air volume of approximately one cubic metre. When the oxygen consumption and carbon dioxide exhalation rates for the assumed level of activity of the workers in the refuge chamber or in a confined space are examined, it shows that each worker requires approximately one cubic metre of air per hour. At the end of a hour this cubic metre of air will contain less than 18% of oxygen and up to 3% of carbon dioxide.

The occupation of a portable refuge chamber without total environmental control, leads to a rapid deterioration of the environment within the chamber as a result of the metabolic characteristics of the occupants. Previous results have shown that an oxygen consumption of approximately 30 litre/hour/worker and a carbon dioxide production of 25 litre/hour/worker are applicable during the occupation of refuge bays and could be used for design purposes.[7]

Carbon dioxide is one of the factors limiting the length of time that workers can remain in a refuge chamber. At high concentrations carbon dioxide acts as a respiratory and central nervous system stimulant and triggers rapid respiration. At a concentration of 2% the respiratory minute volume (RMV) increases by about 50% and at a 4% carbon dioxide concentration this value approximately doubles.[3]

The dramatic impact of metabolic heat on the atmosphere inside a refuge chamber is best understood when it is considered that the value for sedentary metabolism of adult males is taken to be more than 100 watt, which would be the total heat transferred to the environment by each occupant of the refuge chamber.[8]

The need to maintain a breathable and healthy atmosphere thus necessitates the total environmental control of the physical environment within the refuge chamber. This entails an applicable source for the replenishment of the consumed oxygen, a scrubbing system for the removal of metabolically produced carbon dioxide and a way to cool and dry the ambient air. If the abovementioned prerequisites are not met, portable refuge chambers have an occupancy time restriction of only a few hours and a "tomb" effect is created in a very short period of time.

3. GUIDELINES FOR THE DESIGN OF PORTABLE REFUGE CHAMBERS

Basic design considerations must take into account all the above mentioned information and requirements relating to the control of the environment inside the refuge chamber, in order to ensure the maximum survival potential of occupants in the refuge chamber.

The aim is to provide a self-contained portable refuge chamber of modular design and robust construction, which can support approximately 12 workers or one section of a colliery for a period of at least 24 hours. Modular design has the advantage that it can easily be transported to a pre-selected site and it can be extended to accommodate any number of workers by adding additional modules.

The following are proposed concept design parametres :

- The refuge chamber should be self-contained and be able to support 12 workers for a period of 24 hours. This means maintaining an oxygen content above 18% and a carbon dioxide concentration below 0,5%. This implies the replenishment of ±8640 litre of oxygen and the removal of ±7200 litre of carbon dioxide through scrubbing. To maintain a suitable atmosphere in respect of temperature and humidity, the ambient air must be cooled and dried, which means the removal of approximately 32000 Joule and 24 litre of condensate over a 24 hour period of occupation;
- The refuge chamber must function in an explosive and irrespirable atmosphere;
- Although AC power is usually available for use in underground mines, it cannot be guaranteed due to possible incidents like rockfalls and fires. For this apparent reason it is a prerequisite for a

refuge chamber to function independently on DC power for a period of at least 24 hours;

- The chamber must be designed in a gastight manner to allow for low pressurization to prevent ingression of smoke or toxic gases;
- Be of durable construction to withstand low intensity explosions. Portable refuge chambers should be placed in specially designed stubs where the direct concussion from a possible explosion does not impact directly onto the refuge chamber;
- It should be skid mounted to facilitate mobility;
- Must be of modular design in order to accommodate more workers by adding additional modules;
- Should provide basic first aid, sanitary and communication facilities;
- Be provided with a siren, flashing light or reflective markings to assist workers underground in locating the refuge chamber in low visibility conditions;
- Fire resistant materials should be used for the construction of the refuge chamber and its supporting systems;
- A refuge chamber should be versatile to serve if required as an office, medical post, halfway station, etc. and
- Should provide a supply of fresh drinking water.

4. DESCRIPTION OF THE SURVIVAIR RECLAIMABLE REFUGE (RRC) CHAMBER TECHNOLOGY DEMONSTRATOR

The Survivair-RRC technology demonstrator consists mainly of a purpose designed portable refuge chamber, an adapted Survivair-E system for the provision of breathable air and a custom built dual environmental control system to cool and dry the ambient air.

4.1 The Refuge Chamber

The refuge chamber consists of a sitting and a service area. The 2.4 metre long cylindrical sitting unit can accommodate

12 workers and a number of these modular sections can be bolted together. The service area houses the adapted Survivair-E air supply, dual environmental control and power back-up systems. The chamber is of a robust and durable mild steel construction and is mounted on skids. The chamber is also fitted with a chemical toilet, first aid kid, stretcher, fresh water, medical oxygen and a colapsible table. An outside mounted flashing light and siren enable location in low visibility conditions.

4.2 <u>The Adapted Survivair-E Air Supply System</u>

The Survivair-RRC air supply system ensures a safe breathable atmosphere inside the refuge chamber and consists of the following :

- solid state oxygen generating units;
- soda lime carbon dioxide scrubbing system;
- 24 volt battery supply with a charger unit;
- an electronic control module.

<u>Solid State Oxygen Generation</u>

A solid state oxygen generating system releases oxygen through the thermal decomposition of sodium chlorate.

$$2NaClO_3 \xrightarrow{\Delta} 3O_2 + 2NaCl$$

The energy needed for this chemical reaction is made available through the inclusion of a pyrotechnic fuel together with a catalyst in sodium chlorate blocks. Oxygen generation is initiated by pulling the functioning cord of the ignition device which consists of the following :

- a mechanical ignitor with a spring-loaded firing pin on a percussion cap;
- a sodium chlorate ignitor pellet which incorporates a flame sensitive composition and a thermite composition.

The flame sensitive mixture is initiated by means of the flame from the percussion cap transferring energy to the thermite composition which produces the necessary heat to start the thermal decomposition of the sodium chlorate. A chemical and a mechanical filter system ensures the purity of the released oxygen.

One solid state oxygen generator produces ± 2900 litre of oxygen at STP (Standard Temperature and Pressure), with a minimum purity of 99,5% within 45 minutes after activation. It complies with the intrinsic safety standards set out by the South African Bureau of Standards, and is certified for use in all mines by the South African Government Mining Engineer. Any number of oxygen generators can be housed inside the Survivair-RRC depending on the predetermined occupation time and number of occupants.

Carbon Dioxide Scrubbing

Carbon dioxide scrubbing is achieved in the Survivair-E system by circulating the refuge chamber air through a scrubbing unit. A scrubbing unit comprises of a 24 volt blower system and three soda lime canisters stacked on top of each other, each filled with 10kg soda lime. Three additional filled soda lime canisters are also provided. There are many methods reported for the removal of carbon dioxide by adsorption of which soda lime is the least costly. Soda lime consists of 80% calcium hydroxide, 3% sodium hydroxide and 17% water - 116g soda lime adsorb one mole of carbon dioxide, (22,4 litre at STP).

The scrubbing reaction can be summarised as :

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

Power Supply

Although AC power is usually available for use in underground mines, it cannot be guaranteed due to possible incidents like rockfalls and fires. For this apparent reason it is a prerequisite for the carbon dioxide scrubbing system to operate independently on a DC power supply for a period of at least 24 hours.

The scrubbing unit has a set of two 12 volt, long life rechargeable batteries and a 1 amp battery charging unit. A load resistor is used to test the status of the batteries by means of a battery test button on the electronic control module. When installed in a refuge chamber, the charging unit automatically maintains the batteries at full charge from the plugged in AC power supply. The batteries when fully charged, provide a minimum of 24 hours of operation.

Electronic Control Module

An user friendly electronic control display system, consisting of pictograms, is used to operate the Survivair-RRC air supply system. Time cycles for oxygen replenishment and carbon dioxide scrubbing, are pre-programmed into a micro controller.
A 24 volt buzzer is used to remind the user at the end of each event as displayed by the pictograms to proceed to the next step.

A short cycle demonstration mode is used for demonstration purposes and to test the basic functions of the electronic module.

4.3 The Environmental Control System

The purpose of the environmental control system is to maintain both the dry-bulb temperature and relative humidity inside the refuge chamber at acceptable levels. In order to do this the system must simultaneously cool and remove excess moisture from the air. This means that the system must remove both sensible and latent heat. This can be done quite effectively with the aid of a simple air-to-air vapour compression cycle. The design sensible load was set at 1.4kW and the latent load at 0.68kW corresponding to a moisture removal rate of one litre per hour. A person seated quietly should have a metabolic rate equal to one so-called met which is approximately equal to 104.76W.[8] This is usually divided into 65% sensible and 35% latent heat. This means that the twelve occupants should typically contribute 0.82kW to the sensible load and 0.65 litre/hour to the moisture removal rate. The rest of the load is attributed to the heat generated during the activation of the oxygen generating units and the carbon dioxide scrubbing process.

The design conditions within the refuge chamber were set at 25°C dry-bulb temperature and 70% relative humidity and these were therefore also the inlet conditions to the evaporator of the vapour compression cooling system. An important factor to consider when deciding upon the desired outlet conditions of the evaporator (i.e. the cooled air returned to the refuge chamber) is whether to supply a high rate of air flow at relatively high temperatures or a lower air flow rate at lower temperatures. Both of these combinations can be used successfully to obtain the correct sensible and latent cooling. In this case it was decided to opt for the higher flow rate. The advantages of this are two fold namely:

- The air movement associated with high flow rates contributes to the perception of a cooler, fresher atmosphere. This could especially be helpful in a relatively small interior of the refuge chamber;
- The higher outlet temperature results in a higher evaporating temperature of the refrigerant inside the vapour compression cycle. This higher evaporating temperature in turn results in better energy efficiency for the vapour compression cycle.

The system was therefore designed for a total flow rate of approximately 0.172kg/s through the evaporator with an outlet condition of 17°C and a relative humidity of 86%.

In order to enhance the reliability of the system it was decided to split the total cooling capacity between two identical systems, each with its own power supply. The system is designed to have a coefficient of performance (COP) equal to two. This means that the cooling capacity provided by the system is twice the total power consumption. R-134a was selected as refrigerant since it is not yet regulated by the Montreal Protocol as opposed to R-22 which is already subject to a systematic phase out program.

5. EVALUATION OF THE SURVIVAIR-RRC TECHNOLOGY DEMONSTRATOR

The main objective of this evaluation was to verify the Survivair-RRC's ability to support 12 workers for a period of at least 24 hours through maintaining a satisfactory atmosphere inside the refuge chamber. Secondary objectives were the following :

- The ability of the Survivair-RRC air supply system to maintain an adequate volume of breathable air;
- The efficiency of the dual environmental control system in providing appropriate environmental conditions in respect of temperature and humidity;
- To determine the scrubbing efficiency of the soda lime scrubbing system; and
- Whether the combined action of oxygen generation and thermal volume expansion of the air inside the refuge chamber, due to the occupants metabolism, could create a positive pressure in relation to the atmosphere outside the refuge chamber and prevent the ingress of noxious gases.

For the purpose of the evaluation and with the stated objectives in mind, the following parameters were measured and recorded :

- oxygen and carbon dioxide concentrations in the refuge chamber atmosphere;
- environmental temperatures (dry-bulb, wet-bulb and globe) and relative humidity; and
- barometric pressure and pressure differences between the inside of the refuge chamber and the surrounding atmosphere.

6. TEST SUBJECTS

Twelve persons participated in the evaluation test as subjects on the basis of informed consent. The test subjects had an average weight of 68.7 kg, a height of 1.80 m, and a mean age of 24 years. The pulse rate, blood pressure and respiration rate of the test subjects were taken on a routine basis during the test. It was decided that any significant deviation in a subject's vital signs would result in the immediate removal of the person in question and a suspension of the test.

7. EXPERIMENTAL DESIGN AND PROCEDURES

For the purpose of the evaluation test the Survivair-RRC was placed indoors in a facility with climatic control which simulates the temperature conditions of a colliery.

The evaluation was carried out in two consecutive phases, using the same refuge chamber and test subjects.

Phase 1, the test phase lasted for 24 hours during which time the Survivair-RRC air supply and dual environmental control systems were in operation.

The objectives of phase 1 were to determine the following :

- The effect of carbon dioxide scrubbing on the accumulation rate of carbon dioxide;
- The effect of the activation of solid state oxygen generators on restoring the oxygen content of the refuge chamber atmosphere; and
- The efficiency of the dual environmental control system to neutralise the impact of metabolic heat build up and removing the moisture from

the air that results from the scrubbing process as well as normal metabolism.

During both phases certain baseline measurements were taken before the subjects entered the refuge chamber. After the subjects entered the refuge chamber, they were seated and the refuge chamber door tightly closed. An oxygen generator was immediately activated in order to create a positive internal pressure in relation to the atmosphere outside the refuge chamber. At the same time the carbon dioxide scrubber and dual environmental control systems were switched on. It was pre-calculated that an oxygen generating unit would be activated every 6 hours and that the three soda lime canisters need to be replaced after a period of 12 hours.

After the completion of phase 1, the subjects evacuated the refuge chamber and the door was left open for a period of one hour during which time the atmospheric conditions inside the refuge chamber, returned to normal. Phase 2 served as the control to phase 1 and lasted for 1 hour during which time the scrubbing and cooling systems were switched off.

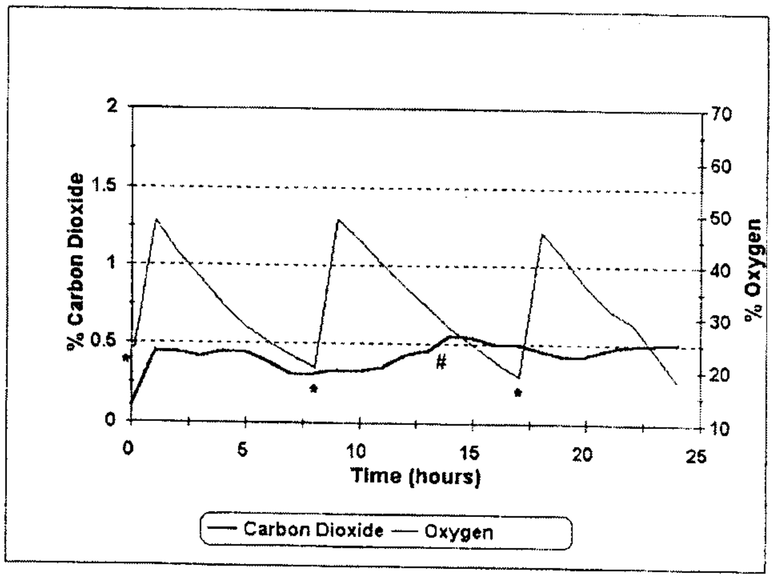
During phase 2, the objective was to determine the rate at which the carbon dioxide build-up took place and the internal temperatures and humidity changes without environmental control.

8. RESULTS

8.1 Oxygen Depletion And Replenishment In The Survivair-RRC

Three oxygen generators were used to replenish the oxygen consumed by the 12 test subjects during the 24 hour occupation period of the test phase. The results as depicted in Figure 1 show the rapid increase in oxygen concentration following the activation of an oxygen generator.

The first oxygen generator was activated immediately after the subjects entered the refuge chamber in order to create a possitive pressure. The released oxygen lasted for a period of 8 hours, which is equal to an oxygen consumption rate of 29.8 litre/person/hour, which corresponds with the results of previous tests conducted in refuge chambers.[7]



* Activate oxygen generator. # Change soda lime scrubber canisters.

Figure 1 : Oxygen depletion and replenishment and carbon dioxide concentration in the Survivair-RRC during a 24 hour occupation period - Test phase.

At the time when the second oxygen generator was activated (after 8 hours) most of the subjects were resting, which resulted in a lower oxygen consumption rate of 26.5 litre/hour. The occupants' consumption rate during the last part of the occupation period was about 32.0 litre/hour, which corresponds with a noticeable higher level of activity during this period.

The results of the control phase (Figure 2), when the environmental control and scrubber systems were not in operation, show an oxygen consumption rate of 35 litre/hour. Although this phase lasted for one hour only, atmospheric conditions within the refuge chamber deteriorated rapidly which could elicit stress reactions from the subjects, affecting their metabolic rates.

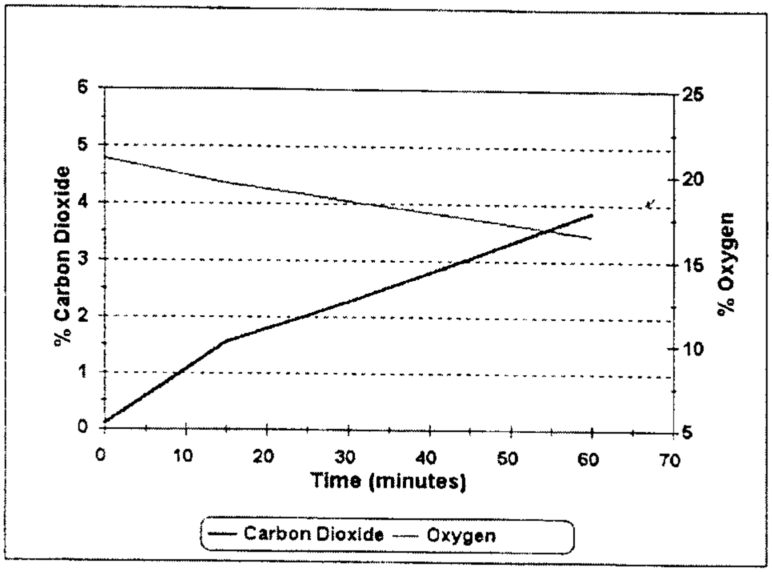


Figure 2 : **Carbon dioxide accumulation and oxygen depletion in the Survivair-RRC without environmental control - Control phase.**

8.2 Carbon Dioxide Accumulation And The Effect Of Scrubbing

Figure 1 illustrates the carbon dioxide concentration in the Survivair-RRC atmosphere during the 24 hours of the test phase. The concentration increases from a background value of 0.11% to stabilize at an average of about 0.45% during the first 6 hours of the test. The concentration then declined to a level of just over 0.30% during the next 6 hours when the subjects' activity noticeably went down and most of them were sleeping. A peak value of 0.55% was observed after 14 hours at which time it was decided to replace the soda lime canisters of the scrubber system. This event took about 5 minutes and led to another peak of about 0.54% in carbon dioxide concentration.

Given the relatively small volume of the refuge chamber and the number of the subjects, it was anticipated that without the use of a scrubbing system the carbon dioxide content of the air in the refuge chamber would increase at a rate of ± 3% per hour.

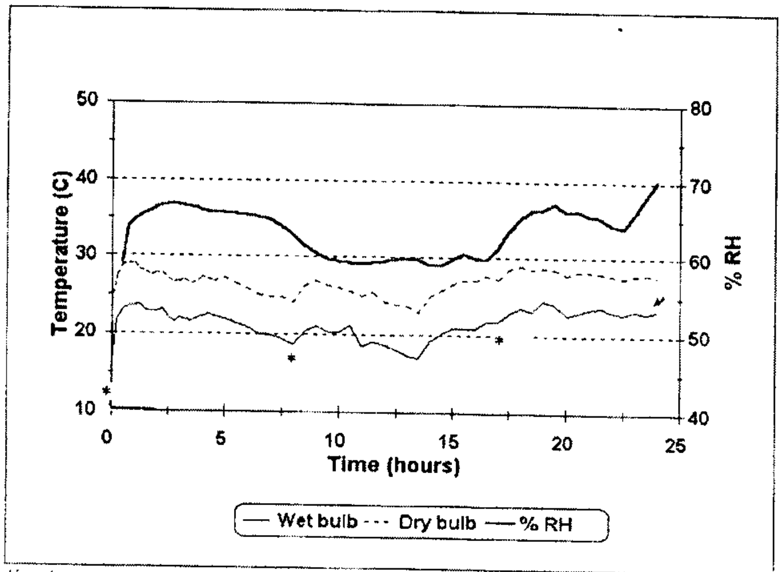
The results of the control phase as depicted in Figure 2, however demonstrate an increase in carbon dioxide concentration of 3.7% during the one hour of occupation when the scrubbing and the environmental control systems were switched off. This confirms that carbon dioxide is a critical factor in determining the life-sustaining potential of a refuge chamber and that the removal of metabolically produced carbon dioxide is of vital importance.

8.3 Environmental Temperature And Relative Humidity

The environmental temperature in the Survivair-RRC was affected during the test due to the following :

- the metabolically produced heat from the 12 subjects;
- heat generated during thermal decomposition of the three oxygen generators that were activated;
- heat generated during the scrubbing process as a result of the interaction between the carbon dioxide and the soda lime; and
- the prevailing environmental conditions of the indoor facility which houses the refuge chamber during the test.

The temperatures values obtained during the test phase are graphically presented in Figure 3. The initial rapid rise during the first minutes in both the wet- and dry-bulb temperatures is indicative of the dramatic impact of metabolic heat on the environmental temperature inside a relatively small refuge chamber. The results show that the activation of oxygen generators had only a limited effect on the environmental temperature.



* Activate oxygen generator

<u>Figure 3 :</u> <u>Change in temperature and RH in the Survivair-RRC during a 24 hour occupation period - Test phase.</u>

The difference of 3°C that was observed between the intake and outlet temperature of the scrubbing systems, indicates the heat contribution during the scrubbing process.

A mean temperature difference of only 1.6°C existed between the mean surface temperature of the Survivair-RRC (24.6°C) and the surrounding atmosphere (23°C), which limited heat loss through radiation.

Notwithstanding this, the dry-bulb temperature in the refuge chamber varied between only 22.3°C and 29°C and the relative humidity between 57.7% and 70.9%. This was indicative of the favourable environmental conditions which prevailed throughout the test period.

During the control phase (Figure 4), the dry-bulb temperature rose from an initial 24.5°C to 29.4°C during the one hour occupation period, with a corresponding rise of 39.9% to 91.7% in the relative humidity, which demonstrates the "tomb" effect when environmental control is not done.

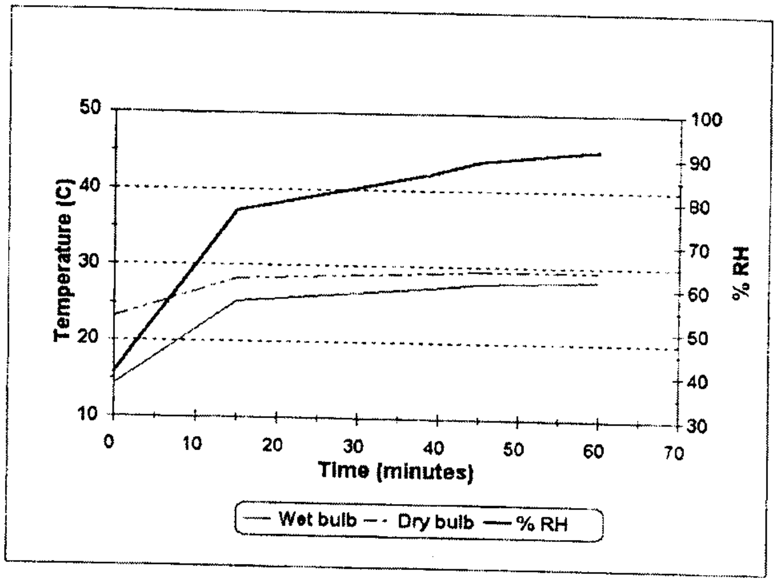


Figure 4 : The change in temperature and RH in the Survivair-RRC without environmental control - Control phase.

The calculated effective temperature (Table 1), as an index of relative comfort is presented in Figure 5 and shows that it corresponds well with conditions that most people will tolerate.[3]

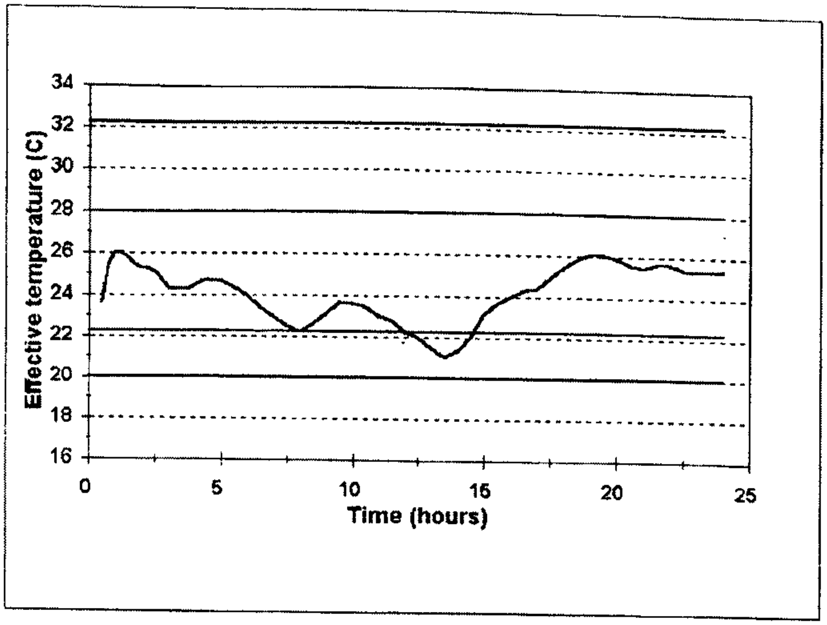


Figure 5 : The prevailing effective temperature in the Survivair-RRC during a 24 hour occupation period.

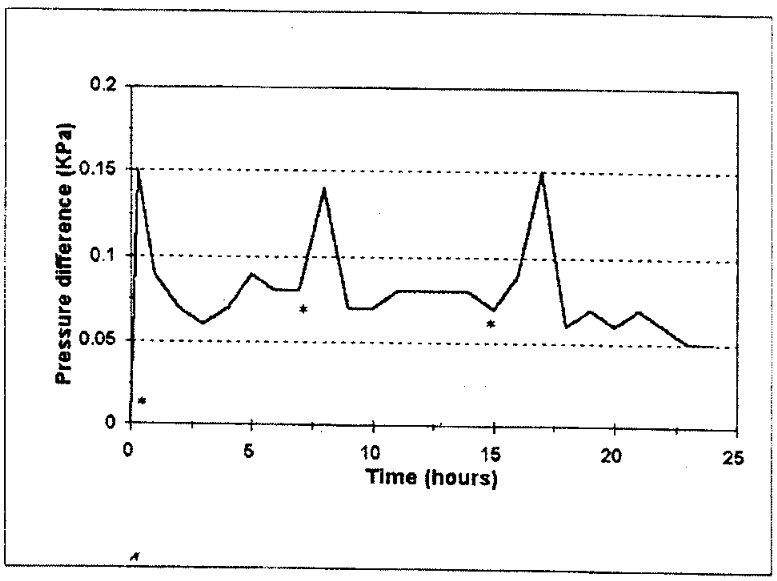
Table 1 : Tolerance limits for clothed healthy subjects at rest.[3]

Effective Temperature(°C)	Comments
20-22.2	Desirable range for long term comfort
22.2-28	Most people will tolerate these conditions
28-32.2	Physiological stresses can be tolerated by most people for several hours and some hardy individuals for 24 hours
32.2 and higher	Severe physiological stresses can be tolerated without injury for only a few hours

8.3 Pressure Difference Between The Survivair-RRC And The Atmosphere Outside The Refuge Chamber

The effective sealing of a refuge chamber is a prerequisite for using a system like the adapted Survivair-E which does not generate a constant positive pressure. If an effective seal of the refuge chamber was achieved, it could be argued that the thermal volume expansion of the air inside the refuge chamber due to the metabolism of the 12 subjects and the scrubbing action, would result in a positive pressure difference between the inside of the refuge chamber and the outside atmosphere.

The periodic release of oxygen through the activation of the oxygen generators would further enhance the pressure difference. Due to the unforeseen leakage in one of the cooler systems, the possitive pressure that was observed, was of a lower order than anticipated. The results obtained during the test phase as depicted in Figure 6 support this theory.



* Activate oxygen generator

Figure 6 : The change in the pressure difference between the Survivair-RRC and the outside environment during the 24 hour test

Although the extent of this positive pressure was relatively small, it is still significant in terms of the prevention of the ingress of noxious gases. The leakage that was observed was from the inside of the chamber to the outside atmosphere.

9. DISCUSSION

The beneficial effect of the use of solid state oxygen for the replenishment of oxygen during the occupation of a refuge chamber, was evident from the results of this evaluation test. The three oxygen generators that were activated during the test phase, replaced all the oxygen that was consumed during the 24 hour occupation period and maintained an oxygen level above 20% throughout this period.

The carbon dioxide scrubbing system prevents the uncontrolled accumulation of the metabolically produced carbon dioxide and verifies the system's ability to maintain safe levels of carbon dioxide during an extended period of occupation.

The environmental control system of the Survivair-RRC proved to be able to maintain favourable conditions in respect of temperature and relative humidity and a healthy atmosphere was ensured throughout the period of occupation.

10. CONCLUSION

The results of the 24 hour evaluation test served to verify that a portable refuge chamber fitted with solid state oxygen generators, a carbon dioxide scrubbing system and an environmental control system could enhance the life sustaining potential of a refuge chamber. The Survivair-RRC technology demonstrator provides a safe breathable atmosphere and is able to support 12 workers for a period of at least 24 hours. The results proved that this concept can be considered as an alternative to the installation of permanent refuge chambers.

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DOCUMENT 17

SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

Draft Final Project Report

Title: PRACTICES AND PROCEDURES TO OVERCOME THE PROBLEMS ASSOCIATED WITH DISORIENTATION AND LOW VISIBILITY IN THE AFTERMATH OF MINE EXPLOSIONS OR FIRES

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Research Agency: CSIR : Division of Mining Technology

Project No.: GEN 101

Date: July 1995

SUMMARY

Poor visibility and disorientation following a fire or an explosion represent major considerations in the development of escape strategies. Apart from the obvious complications such as injuries and the fact that underground personnel can get lost, the distances which could be negotiated with a self-contained self-rescuer (SCSR) would also be affected adversely. The implication is that safety margins may well be reduced to critical or even sub-critical levels.

The plight of underground personnel overcome by disorientation and poor visibility has been highlighted by both local and international experience. Yet, no systematic studies have been undertaken to quantify and address the effects of poor visibility. The purpose of this investigation was to find workable solutions to the problems associated with escapes under conditions of poor visibility, with specific reference to South African coal, gold and platinum mines. The ultimate objective is improved worker protection through optimized escape and rescue strategies.

To quantify the effects of poor visibility and disorientation, underground escape simulations were performed. In this respect volunteers, participating on the basis of informed consent, were requested to escape, blindfolded, from their respective places of work, to designated refuge bays. These escape simulations, performed on coal and gold mines, revealed that:

(a) the speed at which escape routes can be negotiated is reduced significantly irrespective of audible orientation cues; obviously safe travelling distance from the area of work to a back-up facility would have to be adjusted accordingly;

(b) some form of support to assist the escapee to maintain his equilibrium, especially in the case of obstacle-ridden escape routes, and to avoid injury, appears to be crucial; the incorporation of a directional guidance system represents a further element of importance;

(c) belt roads, although generally regarded as suitable, should not be regarded a dedicated primary escape route, and

(d) the pinpoint location of refuge bays and refuge bay entrances in the event of real emergencies appears to have been underestimated severely by planning departments.

Experimental evaluation of guidance systems indicated that a guidance rope or cable, with ferrules (cones) attached to it to provide the necessary directional guidance, appears to be the most feasible method of ensuring that underground personnel will reach a place of safety within reasonable time, and well within the capacity of the SCSR in question. It is therefore suggested that the installation of a guidance rope or cable is fundamental to successful escapes under conditions of poor visibility.

In summary, the main recommendations flowing from this investigation and which could form the basis for the formulation of guidelines to minimize the impact of disorientation and poor visibility, following explosions and fires, are:

- that a guidance rope or cable be installed along dedicated escape routes. The rope/cable should run from a known point in the working sections to a place of safety (i.e. a refuge bay or a cache of long duration SCSRs),
- that an effective early warning method be developed and installed to timeously warn underground personnel against impending danger,
- that methods and means be introduced to assist mine personnel in orientating themselves in working sections, and in following designated escape routes,
- that, owing to complications introduced by low/zero visibility, back-up facilities be placed closer to workings. Previous guidelines in this regard should thus be revised and the installation of intermediate or less formal refuge bays should be considered to reduce travelling distances,
- that travelling roads be regarded as the preferred escape routes instead of conveyor belt roads,
- that personnel be trained to use designated escape routes, i.e. workers should familiarize themselves fully with the escape route by walking the route,
- that the provision of directional guidance to refuge bay doors is imperative, and finally,
- that the possibility of equipping all workers with goggles to provide eye protection against airborne irritants be investigated.

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1 INTRODUCTION

In the South African mining industry, specifically collieries, the deployment of self-contained self-rescuers (SCSRs) is central to most escape strategies. However, the amount of protection afforded is finite and depends on numerous other elements which, collectively, constitute the overall escape and rescue strategy. In this respect the positioning of back-up facilities, e.g. refuge bays, is crucial because such facilities should, in the event of any incident, be able to be reached by all workers without undue fatigue and within the life-saving capacity of SCSRs.

Although considerable research has been directed at establishing maximum safe distances for most conceivable underground escape routes (COMRO User Guide No. 10, 1988), the impact of poor visibility and disorientation was not considered during those earlier studies. However, it should be quite obvious that such complications, apart from injury, would have a profound effect on the distance which could be negotiated to safety while wearing an SCSR. Safety margins may well be reduced to critical or even subcritical levels unless the effects of poor visibility and disorientation are quantified and addressed.

The plight of underground workers overcome by disorientation and low visibility has been highlighted in analyses of incidents both locally and internationally. Yet, no systematic studies have been undertaken to find workable solutions which, in many respects, may well be mine-specific. The purpose of the present study is to address this issue, with specific reference to South African coal, gold and platinum mines. The ultimate objective is improved worker protection through optimized escape and rescue strategies.

2 METHODS

The methodology comprised three distinct phases:

(a) conducting a literature survey and interviewing survivors of a recent incident, as well as Rescue Brigadesmen, to ascertain the exact nature and extent of the problem,

(b) conducting simulated escapes to record experiences and reactions of escapees under conditions of limited visibility, and

(c) evaluating existing and novel guidance systems.

2.1 Literature Survey

An international literature survey was conducted to establish the nature and extent of the problem in the widest possible perspective and to ascertain whether possible solutions exist with respect to escapes under conditions of low (zero) visibility and disorientation. International institutions including the U.S. Bureau of Mines, SIMTARS (Australia), HM Inspectorate of Mines (United Kingdom) and the Mines Rescue Service (New South Wales - Australia) were approached for additional information and/or assistance.

2.2 Interviews

Structured personal interviews were conducted with survivors of a recent colliery disaster. The interview covered experiences with respect to disorientation, low visibility, burning eyes and strategies/innovations relevant to successful escape and rescue. In addition, Rescue Brigadesmen were also interviewed regarding their experiences during rescue operations, particularly with respect to low visibility and disorientation underground.

2.3 Escape Simulations

To establish the performance and experiences of workers under conditions of low visibility and disorientation, volunteers, who participated on the basis of informed consent, were requested to escape blindfolded from their respective places of work to a designated refuge bay. All escapees were accompanied by observers and observations recorded. Experiences and recollections of escapees were also recorded. High seam and low seam collieries, as well as gold mines, were used for this purpose. Some of the escapes were videographed with the ultimate objective of producing an awareness package appropriate to the needs of mines.

2.3.1 High seam colliery escapes

The majority of simulated escapes were performed at Matla Colliery and the specific site and escape route(s) were selected in consultation with management on the basis of being typical for South African high seam collieries (Sections 41 and 44).

Escape routes were along the conveyor belt structure and could be negotiated by the subjects walking in an upright position (unrestricted ceiling height) with an essentially horizontal footwall. Obstacles of note were, however, concrete walls (approximately 0,4-0,5 metres high), protruding concrete slabs, pools of water and staircases over the conveyor belt structure.

In all instances volunteers had been working in the sections under investigation and were therefore familiar with the escape route and were workers employed in the sections mentioned.

Escape simulations to evaluate the MOSES (Mainsfail Operated Sound Evacuation System) guidance system were conducted at Douglas Colliery and at Middelbult Colliery. Escape routes used for this purpose were essentially horizontal roadways with an unrestricted ceiling height and few obstacles. However, the roadway used at Middelbult Colliery had a fair amount of loose coal (duff-coal) and/or stone/coal dust next to the pillars which could be regarded as an additional impediment.

2.3.2 Low seam colliery escapes

These escapes were performed at Hlobane Colliery and the routes were again selected, in consultation with management, to be representative of escape routes on "low seam" collieries. With the exception of the initial stages of the escapes where escapees had to crawl or walk in a crouched position, the routes could be negotiated in an upright position. General characteristics of the two routes selected are presented schematically in Figures 1 and 2. In both instances the footwall was horizontal. The escapees had to negotiate various minor obstacles (pieces of rock, coal, cables) as well as stationary vehicles parked in the roadways.

All the volunteers were employed in the two sections (Section 600 and 620) from where the escapes took place and were, as a consequence, familiar with the escape routes from these sections.

2.3.3 Gold mine escapes

Escape simulations were conducted on Western Deep Levels South Gold Mine in both conventional and mechanized mining sections, and at Winkelhaak Gold Mine. General characteristics of the routes used at Western Deep Levels South are schematically presented in Figures 3 and 4 for the conventional and mechanized mining sections, respectively. The escape routes used at Winkelhaak Mine (conventional section) are depicted in Figure 5.

The volunteers at Western Deep Levels South Mine were ventilation assistants who were familiarized with the escape routes on the day prior to the day on which the experimental escapes were conducted. Workers employed in the two sections used for the purpose of the escape simulations could not be made available due to "production priorities". For the purpose of the investigation it was assumed that the volunteers were adequately trained and familiar with the designated escape route and refuge bay. The escapees at Winkelhaak Mine were normal stope workers who were, as a consequence, thoroughly familiar with the escape route and procedures.

3 RESULTS AND DISCUSSION

3.1 Escape Simulations - Collieries

3.1.1 High seam colliery escapes : day shift

The initial escapes were conducted during the day shift with the conveyor belt running and all underground activities in operation. The results are summarized in Table 1.

Table 1 SIMULATED ESCAPES PERFORMED IN A HIGH SEAM COLLIERY DURING THE DAY SHIFT

Escapee	Occupation	Distance Covered (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)
JP	Shift Boss	315	7,62	0,69
EvZ	Miner	327	9,17	0,59
Julius	Fitter Aide	322	13,5	0,40
Anton	Utility Hand	323	13,3	0,40

The escapes commenced at the waiting place with all four escapees confidently following the belt structure, one hand sliding against the belt structure to provide direction and to maintain balance. It was evident that they were cautious not to get too close to the running belt. Where the conveyor belt structure became too high to be followed all the escapees experienced difficulties (got disorientated and hesitant). They all managed, however, to re-locate the belt structure and to escape to the refuge bay.

The distance which the escapees had to cover to reach a place of safety (i.e. a refuge bay in this instance) was approximately 322 m. The average speed of locomotion was 0,52 $m.sec^{-1}$ and it took them between 7,62 and 13,5 minutes to cover the distance. Under conditions of normal visibility this distance could be covered comfortably in a period of less than 3,5 minutes. This implies that, even with the conveyor belt running and thus providing audio-orientation, the speed of locomotion when visibility is zero is reduced to approximately one-third the speed which can be negotiated under conditions of normal visibility.

All the escapees had difficulty in finding the refuge bay door despite the presence of a siren which was mounted on the hangingwall approximately 10 m from the refuge bay entrance. It was clear that the siren gives an indication of the general vicinity of the refuge bay but does not direct the escapee to the refuge bay door. The siting of the siren as well as the type of siren (continuous versus pulsating sound and frequency spectrum) are aspects which require further investigation.

Escapes from within the section were also performed and these proved to be reasonably easy. The two workers used for this purpose conceded that the sound of the running conveyor belt assisted them in finding the escape route. Obstacles in the section, however, proved to be problematical.

It was evident from these escapes that the sound of the running conveyor belt was a crucial element in successful escapes. It is unlikely, however, that in the aftermath of a fire and or explosion, the conveyor belt will be in operation and it would therefore be inappropriate to rely on conveyor belt noise to provide guidance. Thus, to rely on the sound of the conveyor belt to direct escapees on the designated escape route would be impractical and alternative means should be found.

3.1.2 High seam colliery escapes : post-shift

Escape simulations were also conducted after the night shift with the conveyor belt switched off and general mining operations reduced to the minimum. Escapes commenced in the section after the volunteers were disorientated (i.e., they were blindfolded in the section and taken on a random walk before being instructed to commence the simulated escape).

The majority of the escapees experienced difficulties in finding their way out of the section and locomotion in general could be described as extremely hesitant. In most cases the speed of locomotion did not exceed 0,2 $m.sec^{-1}$ and could be ascribed primarily to two factors:

(a) escapees had no directional guidance, and

(b) no support structure could be located for orientation, support and maintaining balance in an area where many obstacles were anticipated.

All volunteers used in the exercise nevertheless managed to reach the conveyor belt structure after which the speed of locomotion increased significantly. The results are presented in Table 2.

Table 2 SIMULATED ESCAPES PERFORMED IN A HIGH SEAM COLLIERY AFTER THE NIGHT SHIFT

Escapee	Occupation	Distance Covered (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)
GS	Shift Boss	465	15,73	0,49
JF	Miner	473	16,67	0,47
David	C M Operator	587	28,83	0,34
FC	Electrician	437	12,95	0,56
PvdH*	Fitter	640	30,0	0,36
Daniel	Shuttlecar Driver	561	37,6	0,25
HduP**	Shift Boss	693	32,0	0,36
EL	Electrician	699	22,97	0,51

* Person got lost and the escape effort was terminated after a duration of 30 minutes.

** Person also got lost but managed to find his way to the refuge bay in 32 minutes.

The average speed of locomotion recorded for these escapes (i.e. from within the section to the refuge bay unless otherwise indicated) was 0,42 $m.sec^{-1}$ which approximates 25 per cent of the speed during escapes when visibility is normal. On average (discounting the person who lost his way) it took the escapees 20,84 minutes (range 12,95 to 37,6 minutes) to reach the designated refuge bay. Under conditions of normal visibility it requires between 5-8 minutes to cover the same escape distance. It should also be noted that the speed of locomotion was marginally slower compared with escapes conducted during the day-shift when the conveyor belt was running (0,4 $m.sec^{-1}$ versus 0,52 $m.sec^{-1}$).

Problems were again experienced by escapees when the belt structure became too high. In fact two of the volunteers (PvdH and HduP) got lost at this point. Escapee PvdH terminated his escape after 30 minutes. Although he covered a distance of 640 m in this period the effective distance covered in the direction of the refuge bay was only approximately 100 m.

It was apparent that the escape speed at these sections of the conveyor belt structure had to be reduced drastically and could be attributed to the fact that escapees were no longer in direct touch with the structure. It was also of significance to note that under these circumstances the escapees preferred to walk next to a pillar with the outstretched arm (hand) touching the pillar side for orientation and directional guidance.

3.1.3 Low seam colliery escapes

The results are summarized in Table 3.

Table 3 SIMULATED ESCAPES PERFORMED AT A LOW SEAM COLLIERY

Section 600				Section 620			
Escapee's Name	Distance* Covered (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)	Escapee's Name	Distance* Covered (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)
Nlambo	833	20,78	0,67	Mtetwa	761	24,48	0,52
Behalu	833	15,93	0,87	Michael	761	22,48	0,56
Jabulani	833	21,97	0,63	Patrick	761	23,23	0,55
Danda	833	17,88	0,78	Ndwalde	761	41,22	0,31
Johann	833	35,58	0,39	Shabala	761	26,6	0,44

* Distance from where the escape commenced in the section, to the designated refuge bay.

As was the case with high seam colliery escapes, the speed at which the escape routes could be negotiated when blindfolded, was significantly reduced. The average speed of locomotion for the two routes was 0,48 $m.sec^{-1}$ and 0,67 $m.sec^{-1}$ for Section 600 and Section 620, respectively. This represents speeds of approximately 35-45 per cent of that observed during normal vision.

It was very apparent that the volunteers who took part in the investigation were well trained and knew their respective escape routes well. Virtually all the escapees made use of the "life-line" or "stop-switch" cable and/or electrical cables to escape out of the section. Once out of the section the escapees made, without exception, use of the electrical cables which were attached to the roof, for guidance.

One of the escapees made use of a "feeler stick" which he tapped against the overhead electrical cables and/or roof. The side walls were not used because of caving-in. This results in big chunks of coal and rock which make movement next to the sidewalls extremely difficult, if not impossible. One volunteer (Johann - Section 600) got lost in the section but managed to find his way out without assistance. He nevertheless lost valuable time as is evident from Table 3.

Obstacles along the escape routes presented a problem to most of the escapees - particularly big obstacles like a man-carriage and scoops parked in the road ways (escape routes) at the end of the shift. As pointed out the escapees were very familiar with the escape route but these unanticipated obstacles led to considerable confusion.

Although the siren at the refuge bay door appeared to provide general guidance, a number of the volunteers experienced problems in locating the refuge bay door. One of the subjects having arrived at the refuge bay, took in excess of two minutes to find the door. This could become an important factor in a real disaster given the "limited" life-saving potential of the self-contained self-rescuers. The reserve capacity of the SCSR which, in turn, depends on the prescribed escape distances, therefore becomes crucial during such escapes.

In this regard it is of significance to note that the shortest period taken to reach a designated refuge bay was approximately 16 minutes (Escapee Behlu, Section 600). This time period is just within the limits of protection afforded by the Ocenco M-20 SCSR. The majority of the escapees would thus not have made it to the designated refuge bay unless additional means of respiratory protection were provided, which is in fact the case at Hlobane Colliery. It serves, however, to illustrate the importance of having back-up facilities within the limits of protection afforded by SCSRs.

3.2 Escape Simulations - Gold Mines

3.2.1 Escape simulations performed at Western Deep Levels South Mine

3.2.1.1 Mechanized mining section

Inasmuch as the escapes were performed during the day shift the escapees had to negotiate the escape route with all mining activities in progress, including moving LHDs in the road ways (escape ways). To prevent injuries escapees were cautioned where moving LHDs were encountered.

Although the escape route could be negotiated in an upright position obstacles such as ore passes and drains, were potential danger areas. It was not surprising, therefore, that three of the five escapees walked straight into either one of the two ore passes en route to the refuge bay. There is no doubt that ore passes pose a serious danger to escapees under conditions of low visibility and disorientation and that a means should be provided to assist workers in getting around such obstacles. Open drains will also result in injuries, especially leg injuries, which would obviously present a further aggravation.

The escapees made use primarily of pipes and cables, suspended from the hanging wall, to direct them to the refuge bay. Side walls, rail tracks (where available) and even ventilation flow were used to locate the refuge bay. Two of the escapees nevertheless lost their way completely (went into the wrong road ways) and had to be assisted to find their direction to the refuge bay.

Data on the speed of locomotion and duration of the escapes are presented in Table 4. It is of significance to note that the speed of locomotion (average 0,43 $m.sec^{-1}$) was very similar to that observed during simulated escapes performed on collieries. This implies that no distinction should be made between coal and gold mines in terms of maximum safe escape distances.

Table 4 SIMULATED ESCAPES PERFORMED AT WESTERN DEEP LEVELS SOUTH GOLD MINE

Mechanized Section				Conventional Section			
Escapee's Name	Distance Covered (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)	Escapee's Name	Distance Covered (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)
Lennox	727	28,63	0,42	Lennox*	465	26,78	0,29
Wiseman*	727	26,45	0,39	Wiseman*	465	30,60	0,25
Madolo	727	31,38	0,42	Madolo*	465	19,73	0,39
Joseph	727	28,95	0,47	Joseph	465	22,38	0,35
Dumsani*	727	25,67	0,46	Dumsani	465	17,47	0,44

* Escapees lost direction and had to be assisted.

3.2.1.2 Conventional mining section

The results of the escapes conducted from a conventional section are also given in Table 4. The average speed of locomotion recorded (0,34 $m.sec^{-1}$) was less than that recorded for the escape from the mechanized section and can probably be attributed to the fact that three of the escapees lost their way and had to be redirected. This is obviously a reality of any emergency and underlines the importance of proper escape route identification.

The many exits (cross cuts) from haulages represent a major problem for escapees. Three of the five volunteers took the wrong exits and, as a consequence, became lost. It was also apparent that the drains would be the cause of serious injuries to underground personnel attempting an escape. The drains are normally next to side walls and inasmuch as side walls are used to maintain balance and to provide a sense of direction, it would be necessary to cover these drains to prevent unnecessary injuries.

It was noted that although escapees managed to locate the refuge bay, several escapees had difficulty in finding the refuge bay door (and door handle in particular). This problem was noted during the colliery escapes, as well as during escapes performed in a mechanized gold mine section. This is therefore a common shortcoming and illustrates the importance of an apparently trivial element in the escape to safety.

Comments made by the escapees suggest that an intimate knowledge of the working area and of the escape route are fundamental to successful escapes under conditions where visibility is reduced to critical levels.

3.2.2 Escape simulations performed at Winkelhaak Gold Mine

At first glance the escape route used at Winkelhaak Mine appeared to be more complicated and difficult than the conventional stope route used at Western Deep Levels South Mine. However, the route proved to be a relatively easy escape route owing to fewer exits and the fact that in the haulage the escape route was clear of obstacles (drains in particular).

Despite the fact that the escape route could be regarded as "relatively easy", the average speed of locomotion of 0,42 $m.sec^{-1}$ (Table 5) was very similar to that recorded for a mechanized gold mine escape (0,43 $m.sec^{-1}$), and represented only 30 per cent of the speed which could be recorded during normal visibility (1,41 $m.sec^{-1}$). During normal visibility the total escape distance from the stope to the refuge bay could be covered with relative ease in less than eight minutes.

Once again the difficulty in locating refuge bays in gold mines was underlined. One of the escapees walked past the entrance to the refuge bay despite the fact that the gravel on the footwall and the pumps in the pump station (escapees had to walk through the pump station to get to the refuge bay) should have provided the necessary clues to where the refuge bay entrance was. Locating refuge bays under conditions of zero visibility in gold mines appears to have been underestimated and should be addressed as a priority.

Table 5 SIMULATED ESCAPES PERFORMED AT WINKELHAAK GOLD MINE

Escapee's Name	Distance Covered* (metres)	Duration of Escape (minutes)	Speed of Locomotion ($m.sec^{-1}$)
Moses	662	26,42	0,42
Amos**	612	26,50	0,38
Morris	662	25,07	0,44
Keppies	662	28,83	0,38
Osmond	662	23,8	0,46

* Distance from where the escape commenced in the stope to the designated refuge bay.

** Escapee walked passed the refuge bay. Values represent those recorded when he reached the entrance to the bay.

3.3 Escape Simulations with SCSRs

The escape simulations conducted under conditions simulating zero visibility suggested that speed of locomotion was severely restricted and it follows that as a result, the distances which could be covered with body-worn SCSRs in a given time period (i.e. the duration of an SCSR), would also be considerably less. Thus, to quantify the effect of zero visibility escapes on the performance of these devices, escapes were performed with Fenzy Spiral 1 SCSRs under conditions of normal visibility and of zero visibility, using the same escape route.

The results are presented in Table 6. The average distance which could be covered by the escapees under conditions of zero visibility was approximately half (54,6 per cent) of that covered under conditions of normal visibility. This is despite the observation that the duration recorded, on average, was approximately nine minutes longer when escapes were performed blindfolded, thus illustrating the improved economy of slower escape speeds which, in this instance, should be regarded as enforced. The implication of this finding is that maximum "safe face-to-refuge distances" currently recommended (Kielblock and van Rensburg, 1987), should be reduced by half in order to make allowances for poor visibility.

The limited distances which were covered under conditions of zero visibility could be attributed to the reduced speed of locomotion. The average speed of locomotion observed (0,57 $m.sec^{-1}$) was approximately 40 per cent of that observed under conditions of normal visibility. This figure is in agreement with those recorded for the other escape simulations performed, excluding cases where escapees lost their way.

Table 6 ESCAPE SIMULATIONS PERFORMED WITH BODY-WORN SCSRs

Escapee's Name	Normal Visibility			Zero Visibility		
	Duration (minutes)	Distance Covered (metres)	Speed of Locomotion ($m.sec^{-1}$)	Duration (minutes)	Distance Covered (metres)	Speed of Locomotion ($m.sec^{-1}$)
AS	39,6	3 148	1.32	40,6	1 934	0,79
HK	24	1 896	1,32	33,8	997	0,49
TVR	19	1 480	1,30	36,0	897	0,42
CC	39	3 120	1,33	51,0	1 434	0,47
GC	32,4	2 789	1,43	37,4	1 472	0,66

3.4 Evaluation of Guidance Systems

3.4.1 MOSES system

The MOSES system was designed to guide personnel from the work place to a place of safety, such as a refuge bay. This is accomplished by a series of small, roof-mounted units spaced at intervals varying between 30-50 m, which emit both an audible and visual signal in a cyclic routine. The cycle commences at the working face and terminates at the refuge chamber. The system can, however, be changed so that the cycle commences at the refuge bay and terminates in the section. The duration of the entire cycle (and therefore also the intervals of activation between consecutive units) can be pre-set at a control unit which is normally in the refuge bay. Further details are given in Appendix I.

The effectiveness of the visual and audible signals in aiding workers to escape to a safe place was evaluated separately at two different collieries, namely Douglas Colliery (Van Dyksdrift Section) and Middelbult Colliery.

At Douglas Colliery escapees were not blindfolded and as a consequence use was made of the visual signal to escape to the refuge bay which was located approximately 1 300 m from the section where the "escape" commenced. The escapees escaped in four groups with the first group (i.e. fast walking group) reaching the refuge bay after 16 minutes. The fourth group managed to reach the refuge bay in 27 minutes. The speed of locomotion thus varied between 0,8 $m.sec^{-1}$ to 1,35 $m.sec^{-1}$.

In the aftermath of a fire or explosion it is anticipated, however, that the visual signal would no longer be visible or detectable and, could as a result, be rendered useless. A subsequent escape simulation was performed at Middelbult Colliery with escapees blindfolded. The escapees therefore had to rely entirely on the audible signal to direct them to the refuge bay. A summary of the results (with descriptive statistics) is given in Table 7.

Table 7 EVALUATION OF THE MOSES SYSTEM : MIDDELBULT COLLIERY

	Normal Vision*		Zero Vision**	
	Duration (minutes)	Speed of Locomotion ($m.sec^{-1}$)	Duration (minutes)	Speed of Locomotion ($m.sec^{-1}$)
Mean	8,5	1,83	25,3	0,67
Standard Deviation			0,82	0,21
Range			14,5 - 39,5	0,39 - 1,07

*** Visual and audible signal**
**** Audible signal only**

From Table 7 it is evident that the speed of locomotion (0,67 $m.sec^{-1}$) was significantly reduced where only the audible signal was used. This will inevitably have a limiting affect on the distances which could be covered in a given period of time.

All the escapees were disorientated before commencement of the escape to ascertain whether it would be possible for them to re-align themselves and to determine the correct direction of escape. All the volunteers managed to escape successfully in the correct direction although the conveyor belt noise could have been of some assistance in establishing the correct escape direction. Two of the volunteers nevertheless lost their way to the refuge bay despite audible cues and had to be re-directed by observers. This suggests that the system is not 100 per cent fail-safe.

It was of interest to note that all the escapees "held on" to the pillar side (rib side) during the escapes. This observation re-emphasizes the importance of a support structure or some means to maintain balance and direction, and a number of escapees commented that "the physical reassurance of the rib side" played a vital role in the escapes.

The general judgement made by the escapees following the escape with the MOSES system was that it is an aid in providing directional guidance. Reservations were, however, expressed regarding the effectiveness of the system under real escape conditions, i.e. when panic situations prevail. The fact that the system does not provide physical guidance was also pointed out as a potential shortcoming. The opinion was also expressed that training in the use of the system (which implies blindfolding workers) would be a prerequisite in ensuring that escapes with the MOSES system can be effected successfully when required.

3.4.2 Guidance cable

Observations made during underground escape simulations under conditions of zero visibility as well as escapes performed with the aid of the MOSES electronic guidance system suggested that a support structure is not only desirable, but in fact essential. A cable manufacturing company (Haggie Rand) was subsequently approached for assistance in this regard and a 10 mm diameter steel cable, with ferrules (cone-shaped for directional guidance) attached to the cable at 10 m intervals, was manufactured and installed in an underground colliery roadway to assess the efficacy of a guidance cable. The results are presented in Table 8.

Table 8 EVALUATION OF THE HAGGIE RAND GUIDANCE CABLE

Escapee's Name	Normal Visibility		Zero Visibility		Zero Visibility - Cable	
	Escape Time (minutes)	Speed of Locomotion ($m.sec^{-1}$)	Escape Time (minutes)	Speed of Locomotion ($m.sec^{-1}$)	Escape Time (minutes)	Speed of Locomotion ($m.sec^{-1}$)
AS	3,00	1,44	6,73	0,64	3,73	1,16
HK	3,00	1,44	9,37	0,46	3,42	1,27
AVA	3,00	1,44	8,67	0,50	4,43	0,98
JVD	3,00	1,44	14,50	0,30	3,75	1,16
BVS	3,00	1,44	7,23	0,60	4,00	1,08
MJ	3,00	1,44	6,12	0,71	4,88	0,89
HT	3,00	1,44	7,53	0,58	4,12	1,05
TVR	3,00	1,44	8,25	0,53	3,87	1,12
Mean	3,00	1,44	8,55	0,54	4,02	1,09

The total length of the cable was 260 metres and escapes were performed over this distance under conditions of zero visibility without any directional aids and under conditions of zero visibility but with the cable as guidance. Escapes were also performed under conditions of normal visibility for reference purposes.

From Table 8 it is clear that with the guidance cable an escape speed of more than twice the speed recorded during zero visibility, could be maintained. The escape speed with the cable (1,09 $m.sec^{-1}$) represents a value in excess of 75 per cent of that observed during conditions of normal visibility. This finding has a direct bearing on the distances which could be covered in a given period of time and, as a consequence, on maximum safe face-to-refuge bay distances which could be covered with SCSRs.

An additional positive feature of the guidance cable is the significantly lower variation in escape times between escapees, as evidenced by the standard deviations recorded without (2,62 minutes) and with (0,45 minutes) the guidance cable. The smaller variation reflects a much higher confidence in the system and could contribute significantly to improved escape and rescue strategies inasmuch as it would be known at what speed workers would be able to escape and what distances could be covered, for example, with body-worn self-contained self-rescuers.

Although consensus was reached among the volunteers participating in this particular exercise that a life-line (guidance cable) is absolutely essential for escape during zero vision, certain aspects will require further investigation. These include, amongst others, the thickness of the cable (which has a bearing on the mass and consequently also on the handling of the cable), the frequency of directional cones, the ideal height at which the cable needs to be fixed to the sidewall/pillars and some other logistical problems (e.g. fixing of the cable to sidewalls; maintenance; covering roadways) associated with the installation of such a guidance cable/life-line.

3.4.3 Other guidance systems

In our investigations into possible guidance systems two additional systems were identified namely:

a) the Matjatula device and
b) the Parkerscape

3.4.3.1 Matjatula device

This system consists of a straining wire which runs next to the sidewall/pillars and is attached to the sidewall/pillars by means of a piece of flat iron bolted to the sidewall so that the wire runs at hip height approximately 0,5 m from the wall. Attached to the piece of flat iron is a "pig tail" through which the straining wire runs. The pig tail also acts as a directional guide. A diagram is presented in Figure 6.

The system has not yet been installed in a working section and, as a consequence, could not be evaluated. The operational principle of this system and that of the Haggie Rand guidance cable are similar and there is no reason to question the potential life-saving capacity of the system.

3.4.3.2 Parkerscape

This system consists of a rail (similar to a curtain rail) attached to the hangingwall which runs from close to the work place to a place of safety, for example, a refuge bay. The workers carry with them a lanyard to which is attached a "clip on" mechanism. Once clipped onto the rail the escapee can travel freely in one direction only (i.e., in the direction of the refuge bay).

The feasibility of this system has not yet been evaluated. Further information is nevertheless given in Appendix II.

4 GENERAL DISCUSSION

In the aftermath of fires and explosions, smoke and other particulate matter can become a severe hindrance to the safe evacuation of mine personnel. This has been borne out by several incidents locally (unpublished information) and internationally (Vaught et al. 1992; Cole et al. 1993). It is generally recognized that the smoke which fills mine openings (especially in collieries) induces a visual "white out" and reduces visibility to near zero. Workers trapped in these conditions may wander aimlessly, eventually succumbing to exposure to toxic gases, confusion, exhaustion or panic. Industry-wide it has been accepted that methods to guide miners through dense smoke will contribute greatly to saving the lives of those who survive the initial blast during mine fires and explosions. The main objective of this investigation was therefore to identify possible practices and procedures to overcome the problems associated with low (zero) visibility escapes.

It should, however, be pointed out that although it is generally accepted that the lack of visibility is a real problem, smoke cloud irritants are often ignored as a possible aggravating factor. It is well known that smoke clouds contain a variety of sensory irritants that can make it impossible to see or breathe. For example, hydrochloric acid (HCL) is a common combustion product in conveyor belt fires. While not as lethal as carbon monoxide it is a severe eye, nose and throat irritant at concentrations of 100 ppm (Purser, 1988). Tewarson and Newman (1981) gave 50-100 ppm as the critical value for escape from fires.

In experiments conducted by Kissel and Litton (1992) it was shown that severe sensory irritation can take place, even at carbon monoxide levels that do not represent an immediate danger. The carbon monoxide concentration and corresponding subjective sensations are given in the table below:

CO Concentration	Subjects' Responses
≤ 40 ppm	Mild discomfort. Breathing laboured and eyes mildly irritated.
≈ 80 ppm	Hard to breathe. Eyes sting/stinging eyes.
≈ 160 ppm	Very difficult to breathe. Severe eye irritation. Could barely see.

These results confirmed findings of Rasbash (1975) and Jin (1981) and indicated that not only smoke, but also sensory irritants, could be a contributing factor to visibility problems experienced by escapees in the aftermath of fires and explosions. Kissel and Litton (1992) concluded that during mine fires (particularly during the early growth stage) escapees will meet with visibility problems before critical carbon monoxide values are reached.

The above clearly suggests that, irrespective of mining operation, smoke with its variety of sensory irritants, is a major factor to contend with. Means to provide reliable eye protection should, therefore, be investigated. In this context it should also be noted that although it is generally accepted that in non-coal operations the propagation of a fire is mostly slower compared to what the case would be in a coal mine, evidence exists that incidents have occurred in hard rock mines where visibility deteriorated at such a rate that travelling, and therefore, escape, was impossible (Unpublished SIMRAC Project Report).

Limited documented information is available on experiences and responses of survivors of incidents where low visibility was a serious limiting factor, particularly with respect to innovations relevant to escape. Structured, open-ended interviews were nevertheless conducted with workers who escaped a major fire at Black Diamond Mine in the USA (Mallett et al. 1993). Although this paper discusses social and technical factors associated with underground coal miners' reactions to their operation's warning system, reference was made to the physical escape and the experiences of the workers.

Mantrips were used during the initial stages of the escape until smoke was encountered which severely limited visibility. At this point workers were left with only those signs and symbols that had been placed in the mine to direct them in case of such an emergency. As is common practice, reflectors were hung near the roof of entries and reflective arrows located at intersections pointed in the outby direction.

Most of the miners interviewed mentioned that reflectors were difficult if not impossible to see in dense smoke. In essence, customary methods of marking escape ways did not prove effective during the emergency situation. Another problem that emerged from the interviews was that miners did not necessarily trust the markings to be unambiguous. Most of the miners who escaped from the smoke-filled sections of Black Diamond agreed that methods of marking escapeways were inadequate.

Since many evacuating workers either could not see or did not trust symbols that marked their escapeways, they used other devices to help them find their way out of the mine. Some used "signs" other than reflectors and arrows, others used their knowledge of the mine's layout, and individuals who did not think they were capable of finding their way out relied on getting directions from other miners. Stoppings were used as markers to help some workers find their way down the escape ways. Another device that was used involved the positioning of pipes, such as those which carried water into the mine. By placing their hands on a pipe that went in a known direction miners could use it as a guide. While they were not trained to do so, the escaping miners seemed to impute more utilitarian value to common permanent mine items than they did to the official escapeway markers.

Crews on all three sections involved in the escape contained at least one person who was capable of leading others from the working section to a safe area. Like the use of unofficial "signs" referred to above, the "follow the leader" technique played a more important role in helping workers to evacuate the mine than did the escapeway markers intended for that purpose.

From the above, as well as interviews conducted with survivors of a recent local colliery disaster, it became clear that clear-cut solutions to the problem of low-visibility do not exist. However, the escape simulations performed under conditions of zero visibility contribute significantly to our knowledge regarding the experiences of escapees and the understanding of problems associated with such escapes. The most important findings emanating from these investigations were:

a) the speed at which escape routes can be negotiated is reduced considerably - even under conditions where the sense of hearing can assist the escapee in locating familiar structures, such as transformers or following the sound of the conveyor belt structure,

b) the slower speed at which escapees are forced to negotiate escape routes under low visibility conditions has a direct bearing on the distances that can be covered within a specified period of time; the implication is that distances between working places and back-up facilities should be considerably less than those currently recommended (Kielblock and van Rensburg, 1987) with respect to the use of SCSRs. Although the devices last longer due to the slower speed of locomotion and the resultant reduction in physiological demand, this does not necessarily compensate for the lower speed of locomotion in terms of distances covered. Moreover, the element of panic has not been taken into account in these observations,

c) a support structure, in agreement with comments made by survivors of the Black Diamond disaster, is required to enable escapees to maintain balance, especially when escapes are attempted over uneven terrain or where obstacles are present,

d) directional guidance is of crucial importance. Means should thus be provided to ensure that escapees escape in the right direction along the designated escape route,

e) dedicated escape routes clear of obstacles and/or hazards are essential. In this regard belt roads cannot be considered to be satisfactory as an escape route due to the many obstacles associated with the belt structure and the fact that conveyor belt structures are symmetrical in design;

f) back-up facilities in the form of refuge bays form an integral part of escape strategies and should be recognized as such,

g) a guidance cable/rope appears to be the only feasible solution to effect successful escapes under conditions of zero visibility, and

h) sirens at refuge bays do not provide satisfactory guidance to locate refuge bay doors, particularly in collieries.

The installation of a guidance rope or cable with ferrules (cones) provides an example of a feasible directional guidance system. The effectiveness of such a guidance cable will, however, depend on workers locating the cable in the event of a disaster. The means to guide workers to the guidance cable needs to be investigated and the entire system assessed.

It should, however, be emphasized that the effectiveness of a guidance cable is also dependent on other factors. Timeous reaction to indications of an incident underground will be crucial in ensuring that workers will reach the guidance rope/cable prior to conditions of zero visibility developing. Mechanisms to warn workers of impending danger are therefore required. However, such systems/devices are not readily available and will have to be developed.

The importance of effective communication has also been highlighted during incidents locally and internationally. Insufficient communication regarding the nature, location and magnitude of the problem appears to be a major problem, particularly with respect to the decision making process.

However, the complete lack of communication in many instances could be regarded as an even bigger problem. It is generally accepted that a telephone system is impractical as a means of warning underground personnel and that other means of warning be investigated to alert personnel of impending danger.

The MOSES system should be regarded as an aid, particularly under conditions of low visibility where the visual signal can be followed. However, under conditions of zero visibility (i.e. conditions where light signals will not be visible) where escapees would have to rely exclusively on an audible signal for direction, findings to date proved to be less promising and an over reliance on the MOSES system, to the exclusion of others, is clearly not indicated.

Although the MOSES system provides directional guidance, the system has no positive effect on the speed at which escape routes can be negotiated in zero visibility. As a result back-up facilities will have to be much closer to working areas than is currently the practice. The exact distances which could be covered with the MOSES needs to be established.

The feasibility and effectiveness of other guidance systems (Parkerscape - Greenside Colliery; Matjatula device - Witbank Consolidated Colliery) have not been evaluated, primarily due to the lack of full development for trial purposes. It is recommended that this be done and results of such investigations be communicated to industry.

5 CONCLUSIONS

5.1 Both locally and internationally there is consensus that disorientation and low visibility, in the aftermath of fires and explosions, are major considerations in underground escape and rescue strategies. However, practical and proven solutions, with the requisite degree of flexibility to permit general application, are not readily available.

5.2 On the basis of case reports available evidence suggests that visibility deteriorates so rapidly in many instances that zero visibility should be the only scenario used when considering possible solutions, particularly in coal mines. This assumption has been verified by local rescue brigadesmen during rescue and fire fighting operations underground.

Although it is generally accepted that in non-coal operations (e.g. gold mines) the propagation of a fire is mostly slower compared to what the case would be in a coal mine, evidence exists of incidents that have occurred in gold mines (LHD fires; blasting fumes) where visibility deteriorated at such a rate that travelling, and therefore escape, was virtually impossible. It is, concluded that escapes under conditions of zero visibility should also be catered for in non-coal operations.

5.3 Due to the rapid and continuous change of working faces, holings and machine positions in the working areas, spatial orientation in collieries in particular, appears to be a problem.

5.4 Escape simulations performed on coal and gold mines under conditions of zero visibility revealed that:

a) the speed at which escape routes can be negotiated is reduced significantly irrespective of audible orientation cues; obviously safe travelling distances from the area of work to a back-up facility would have to be adjusted accordingly,

b) some form of support to assist the escapee to maintain his equilibrium, especially in the case of obstacle-ridden escape routes, and to avoid injury, appears to be crucial; the incorporation of a directional guidance mechanism represents a further element of importance,

c) belt roads, although generally regarded as suitable, should not be regarded as a dedicated primary escape route, and

d) the pinpoint location of refuge bays and refuge bay entrances in the event of real emergencies appears to have been severely underestimated by planning departments.

5.5 Escape simulations performed with the assistance of a commercially available electronic guidance system (MOSES system) suggests that the system should be regarded as an aid, particularly under conditions where a visual signal can be followed. Under conditions of zero visibility where escapees have to rely exclusively on the audible component for direction, the outcome could be jeopardized. Training in the practical use of the system, in any event, appears to be crucial to effect successful escapes.

Although the MOSES system provides directional guidance, the system has no positive effect on the speed at which escape routes can be negotiated in zero visibility. As a result safe travelling distances will not necessarily be increased by the use of the MOSES system. Under such conditions, back-up facilities will have to be closer to working areas than is currently practised.

5.6 The experimental installation of a guidance cable with ferrules (cones) attached to it to provide the necessary directional guidance, which will run from the section to the refuge bay, appears to be a feasible method of ensuring that underground personnel will reach a place of safety within a reasonable time and well within the capacity of the SCSR in question. Examples of similar systems have been installed on some collieries and need to be evaluated in order to consider an optimised system.

6 RECOMMENDATIONS

6.1 Timeous reaction to indications of an incident by underground workers appears to be of vital importance in ensuring that workers reach a positive guidance system or a place of safety prior to conditions of zero visibility. An effective early warning method which will ensure the immediate reaction by underground personnel is therefore required. A telephone system appears to be inadequate for this purpose and other means of warning should thus be investigated to alert underground personnel to impending danger. A manually activated siren located at the section switch gear (collieries), to warn workers in the section and possibly to direct them to the section switch gear if necessary, should be considered and its effectiveness evaluated. In other mining operations different arrangements would be applicable.

To cater for the case of an explosion, an (electronic) warning device which could be activated by the explosions, and associated gases, should be explored. Distinguishing goaf falls from explosions would be impossible by pressure only. There are pressure activated switches available and current technology can be adapted for the development of this device.

6.2 To overcome the problems associated with spatial orientation in a colliery section it is proposed that pillars be marked with a road way number for at least three roads from the face. Markers should be attached in a specific position to enable personnel to orientate themselves spatially. Markers should be added as the face advances.

6.3 In collieries section personnel need to be trained to use the trailing cables of machinery (i.e. the continuous miner, roof bolter etc.) to guide them to a known point in the section. It is recommended that this point be the section switch gear area.

6.4 Due to complications, introduced by low/zero visibility, back-up facilities in the absence of a positive guidance system, should be placed within 500 m from work areas. However, with a positive guidance system this distance could be extended significantly. The exact distance will be determined, however, by escape route configurations and terrain. Individual cases should thus be investigated.

6.5 To compensate for the limited distances that can be covered under conditions of low visibility and disorientation the installation of intermediate, less formal refuge bays, should be considered to shorten the escape distance. Transportable self-sustaining refuge bays are under investigation and systems are becoming commercially available. Positions of these informal refuge bays on highveld collieries could be accurately pinpointed on mine plans to access surviving miners by means of borehole with as little delay as possible.

As an alternative caches of long duration SCSRs, strategically sited, could be considered to enable workers to reach a more formal refuge bay.

6.6 The positive escape system should be linked up with a known point in the working sections. The **recommended positive escape system consists of a continuous guidance rope/cable** which will be installed along the dedicated escape route and will run from a known point in the working sections to a place of safety (refuge bay or a cache of long duration SCSRs). In the case of refuge bays the guidance rope must run up to the refuge bay door. The whole system needs to be moved forward regularly as the face advances . At traffic intersections and/or roadways a slack rope can be used with or without directional brattices to allow vehicle movement.

6.7 Where installation of a guidance cable would be impractical, directional brattices could be erected to direct escapees in the right direction or onto the escape path.

6.8 In collieries it is recommended that travelling roads be regarded as the preferred escape routes instead of conveyor belt roads. The rationale is that:

a) travelling roads are normally used by workers on a daily basis to enter the mine and to leave the mine at the end of the shift. Conveyor belt roads are not normally used and as a result workers do not, and cannot, familiarize themselves with these routes,

b) travelling roads are normally free of obstacles on the floor. This would minimize possible injury and higher escape speeds could be maintained. Moreover, there is no moving equipment that can cause injury, and

c) conveyor belt structures are symmetrical in design. As a result they do not provide any guidance with respect to direction. If, however, conveyor belt structures are used, it is recommended that the structures be marked on both sides of the structure to give tangible directional guidance.

6.9 All escape routes should be marked with reflectors indicating the correct escape direction.

6.10 Underground personnel should be trained to use the designated escape routes, i.e. they should familiarize themselves fully with the escape route by walking the route at regular intervals, for example once a week. This should be irrespective of the presence of a guidance cable or electronic guidance systems like the MOSES. In fact, where the latter system is installed it becomes imperative that training be done under conditions which simulate zero visibility.

6.11 All undesired access points, for example unused entrances, should be barricaded or fitted with a guidance system to prevent accidental entry under conditions of zero visibility.

6.12 The location of the siren at refuge bays - specifically in collieries where the bord and pillar method of mining is used - should be reconsidered. The type of siren (i.e. continuous versus pulsating as well as frequency spectrum) should be investigated and specific guidelines formulated in this regard.

6.13 Because of the ineffectiveness of sirens in guiding people to the refuge bay door directional brattices could be installed in the vicinity of the refuge bay to assist with the location of the door. Guidance should be provided right up to the door where flashing lights and sirens should be positioned. Moreover, the handle should be easily accessible.

6.14 The possibility of equipping all workers with goggles to provide eye protection against airborne irritants, substances which could cause eye irritation, should be investigated. As an additional safety measure all escapees should use their gloves during an escape to prevent possible hand injuries.

6.15 A number of outstanding issues have been identified which still need to be addressed. These include:

a) the design and development of an effective system to guide escapees to the guidance system,

b) the assessment of the efficacy of other guidance systems such as the Parkerscape and Matjatula device,

c) the design and development of an effective early warning device which will ensure the timeous warning of underground personnel in case of fires and/or explosions,

d) identifying means of improved communication in the underground environment,

e) the development of mobile self-contained refuge bays, and

f) establishing safe-travelling distances which could be covered with the MOSES system.

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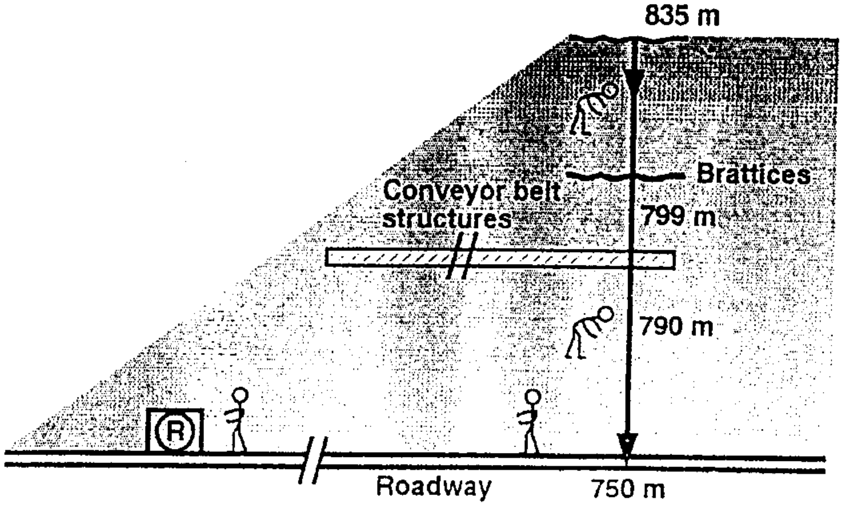


Figure 1 GENERAL CHARACTERISTICS OF THE ESCAPE ROUTE AT HLOBANE COLLIERY - SECTION 600

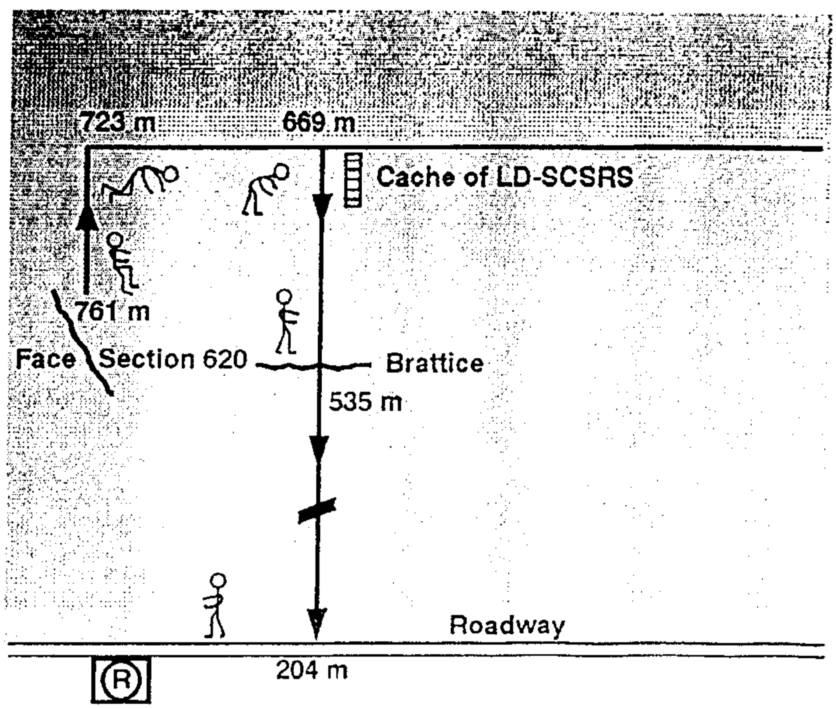


Figure 2 GENERAL CHARACTERISTICS OF THE ESCAPE ROUTE AT HLOBANE COLLIERY - SECTION 620

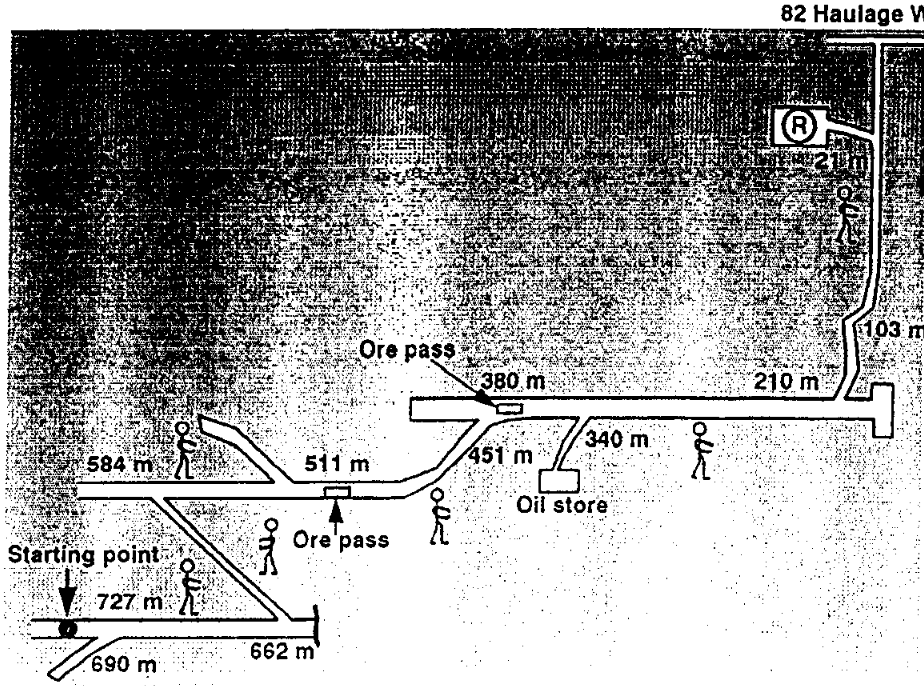


Figure 3 GENERAL CHARACTERISTICS OF THE ESCAPE ROUTE AT WESTERN DEEP LEVELS SOUTH GOLD MINE - TRACKLESS MINING SECTION

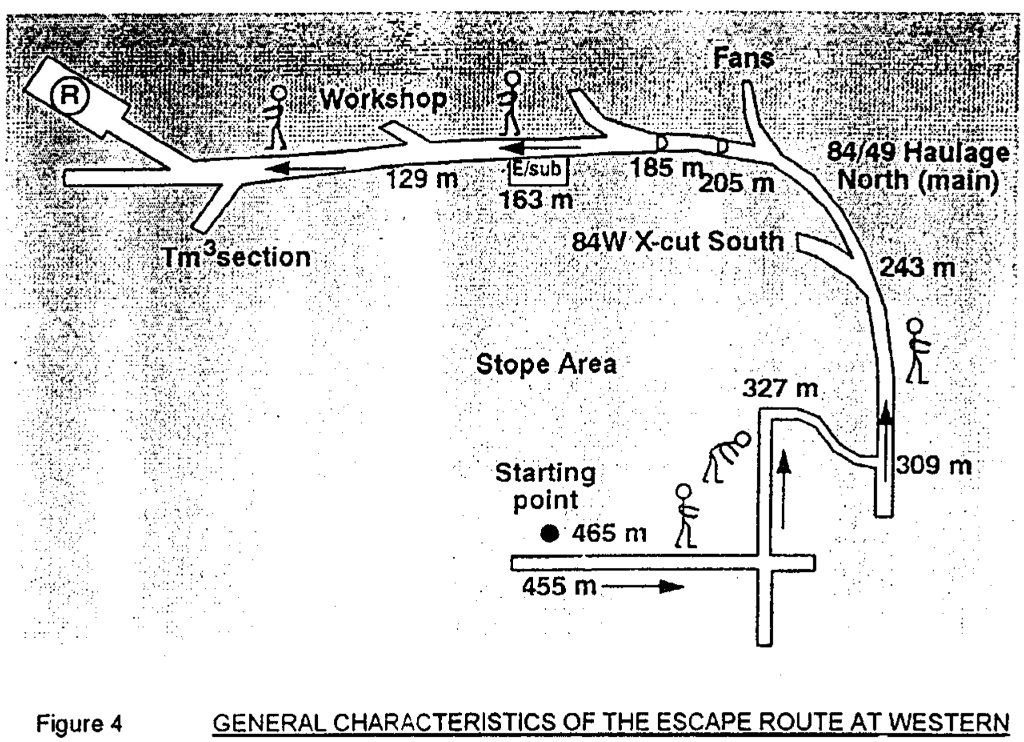


Figure 4 GENERAL CHARACTERISTICS OF THE ESCAPE ROUTE AT WESTERN DEEP LEVELS SOUTH GOLD MINE - CONVENTIONAL SECTION

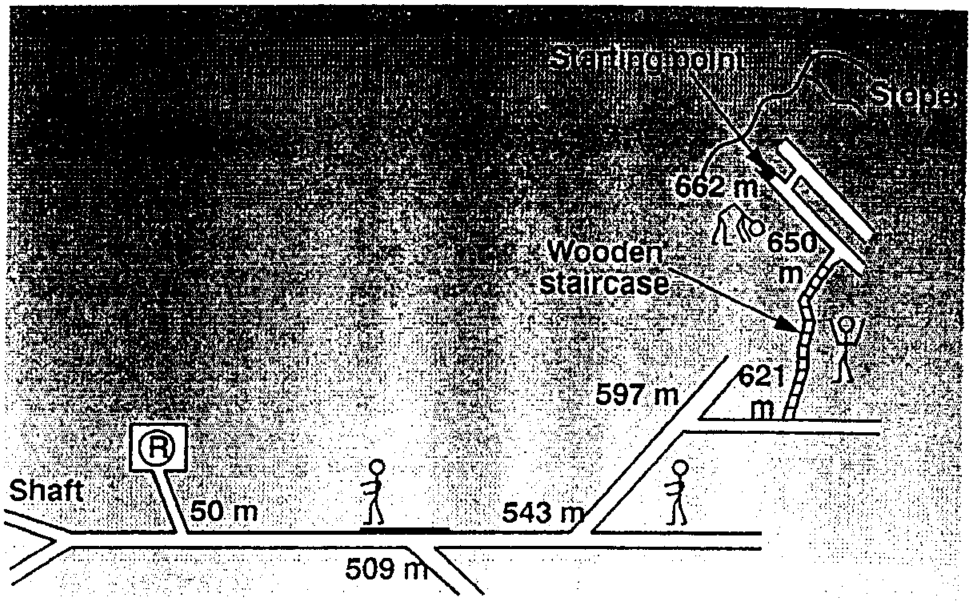


Figure 5 GENERAL CHARACTERISTICS OF THE ESCAPE ROUTE AT WINKELHAAK GOLD MINE

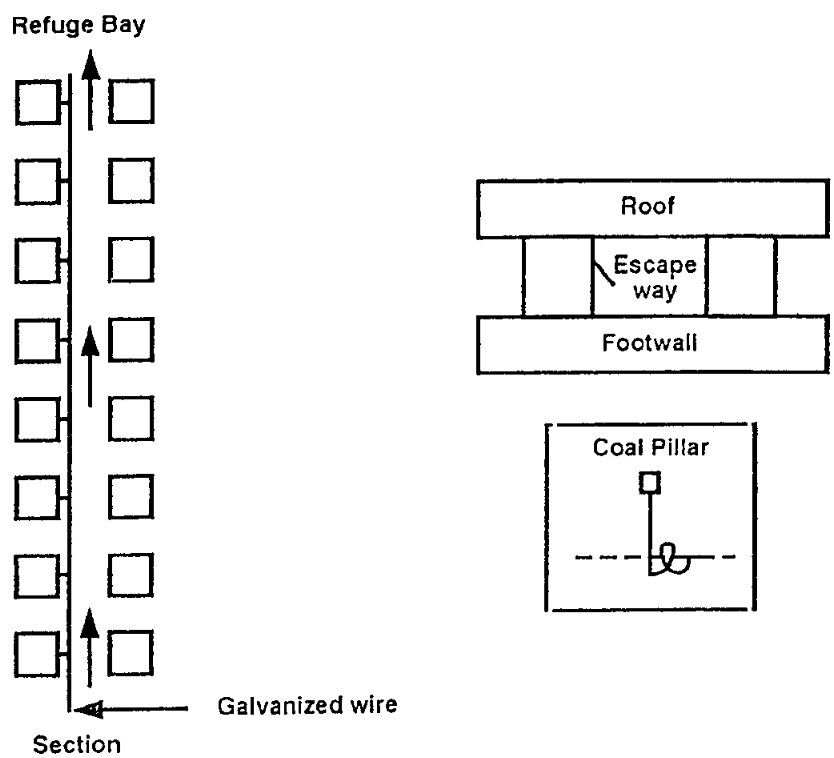


Figure 6 DIAGRAMMATIC PRESENTATION OF THE MATJATULA SYSTEM

APPENDIX I FURTHER INFORMATION REGARDING THE MOSES SYSTEM

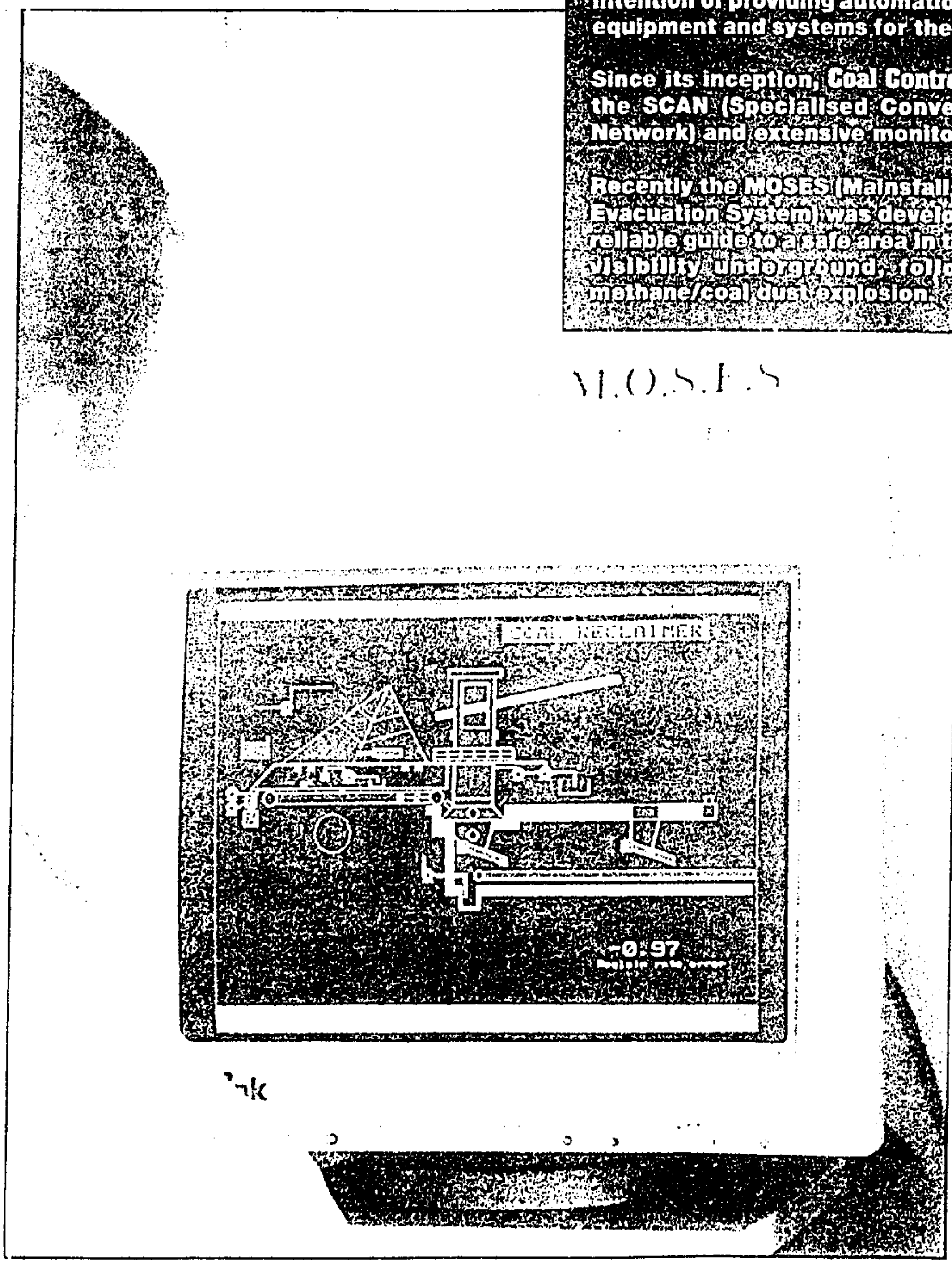
COAL CONTROL FOR SAFER AUTOMATED MINING

Coal Control is centred in Witbank in order to provide the best possible service to the South African coal mining industry.

The company was started in 1990 with the intention of providing automation and monitoring equipment and systems for the mining industry.

Since its inception, **Coal Control** has developed the SCAN (Specialised Conveyor Automation Network) and extensive monitoring systems.

Recently the MOSES (Mainstall Operated Sound Evacuation System) was developed to provide a reliable guide to a safe area in the event of zero-visibility underground, following a fire or methane/coal dust explosion.



COAL CONTROL

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COAL CONTROL

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SCAN

SPECIALISED CONVEYOR AUTOMATION NETWORK

I.A. M787/K725-M787/K709

SCOPE

To provide an effective intelligent conveyor control system which will indicate its status at any given time.

To provide a control unit which will be as self contained as possible.

To provide a conveyor trip switch system which will be fail-safe as well as intelligent.

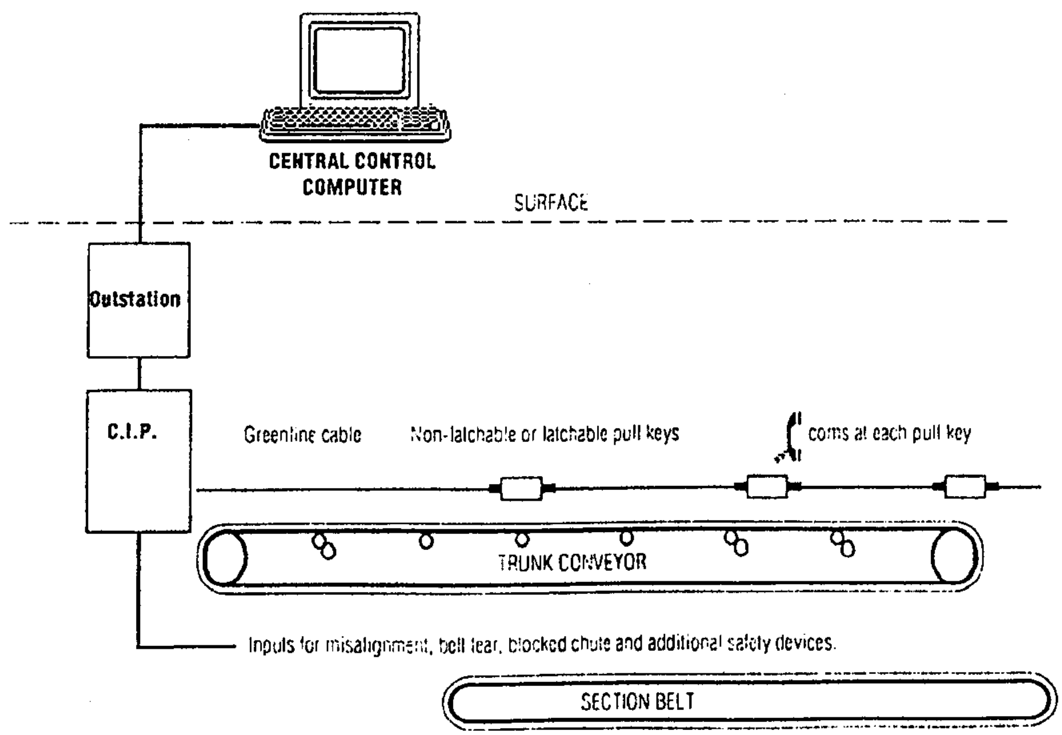
To provide the same standard of safety and control device inputs to meet the requirements of a fully integrated system.
To effectively emit a pre-start warning prior to the conveyor starting.

To automate the conveyor network with facilities to link it to a SCADA based system.

SYSTEM

The Coal Control designed SCAN system offers the following features:-

1 - Interface with SCADA
2 - System status by LCD display.
3 - Digital inputs for the following events:
a) Sequence b) Belt slip c) Belt tear d) Bunker full
e) Belt misalignment f) Blocked chute
4 - Digital inputs for remote START and STOP.
5 - Dual relay outputs for motor START with internal sequential timing.
6 - Pre-start warning initiation with positive proof as to audio emission.
7 - Voltage-free contacts for interlocking section conveyors.
8 - The system provides line fault indication of the following:-
a) Address of tripped stop switch, scrolling in the event of more than one unit tripped.
b) Indication as to the number of units not emitting the pre-start warning as well as showing their location.
c) Cable fault indication and showing location.
9 - Auto-ranging through each stop switch in circuit with a fail-safe ELT *(End of Line Termination link)* fitted in the last unit.
10 - Either latching or non-latching stop switches.
11 - Control units in flameproof enclosures if required.
12 - A **MOSES** *(Mainsfail Operated Sound Evacuation System)* will be initiated in the event of a power failure.



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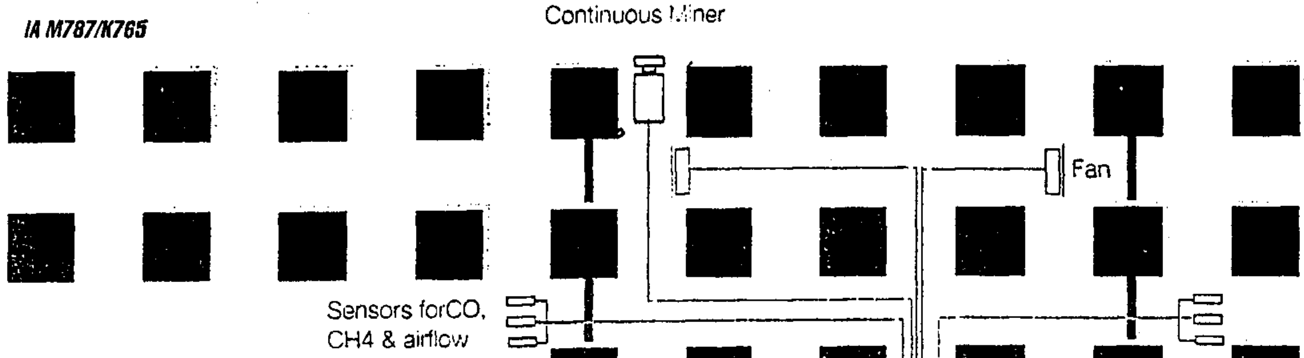
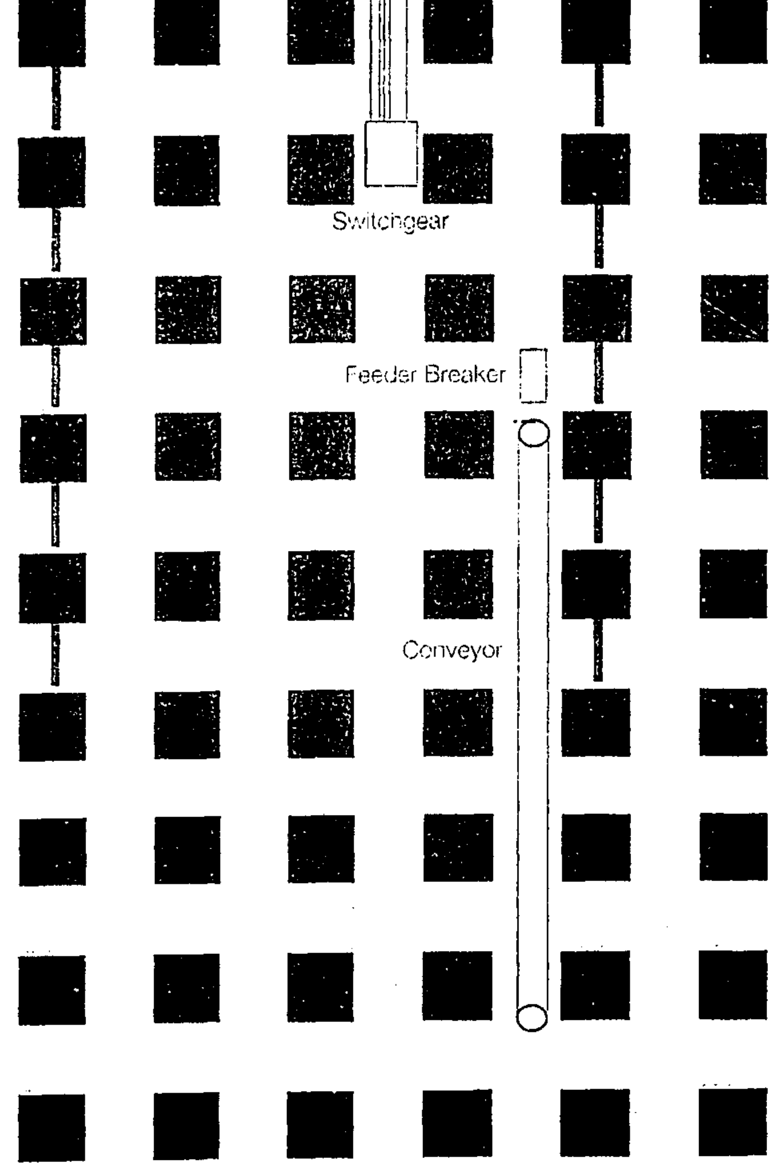
COAL CONTROL ENVIRONMENTAL MONITORING

IA M787/K765





SCOPE

To ensure the safest possible underground working conditions, it is imperative that the environment in the working areas be monitored on a constant ongoing basis. Environmental conditions concerns the amount of methane, carbon monoxide, and the flow of air in the ventilation system.

In order to effectively monitor these conditions the accumulated data from all the working sections, as well as other critical areas underground, must be relayed to a centralised control room on the surface.

SYSTEM

Coal Control has designed a SCADA based system which is compatible with most existing telemetry systems.

The system incorporates an EMO *(Environmental Monitoring Outstation)* which is located in the sub station closest to the section. The EMO is then coupled to an Environ card mounted in a flameproof enclosure located close to the switchgear in the section. The Environ card is powered from a 220 V source and provides an IS supply to the sensors located in the return airway of the section. The unit thus monitors the percentage of methane, CO in ppm, and airflow in m/sec

This data, which is continually transmitted to the central control room, thus provides a means of monitoring the build-up of potentially lethal gases, or lack of adequate ventilation.

This system is currently in service in South African coal mines.

COAL CONTROL

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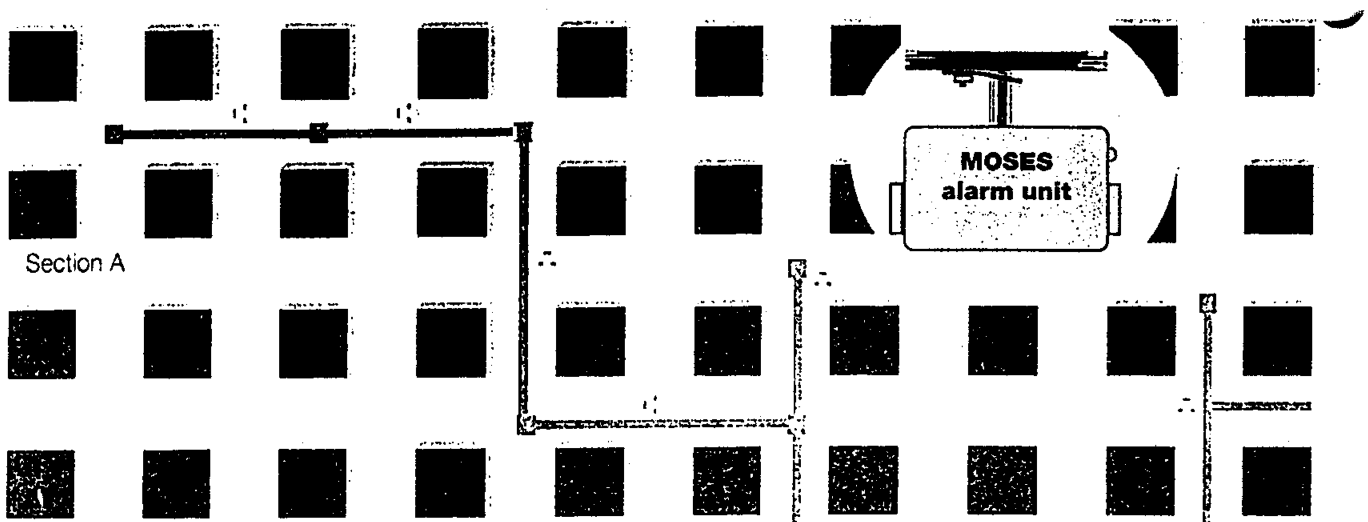

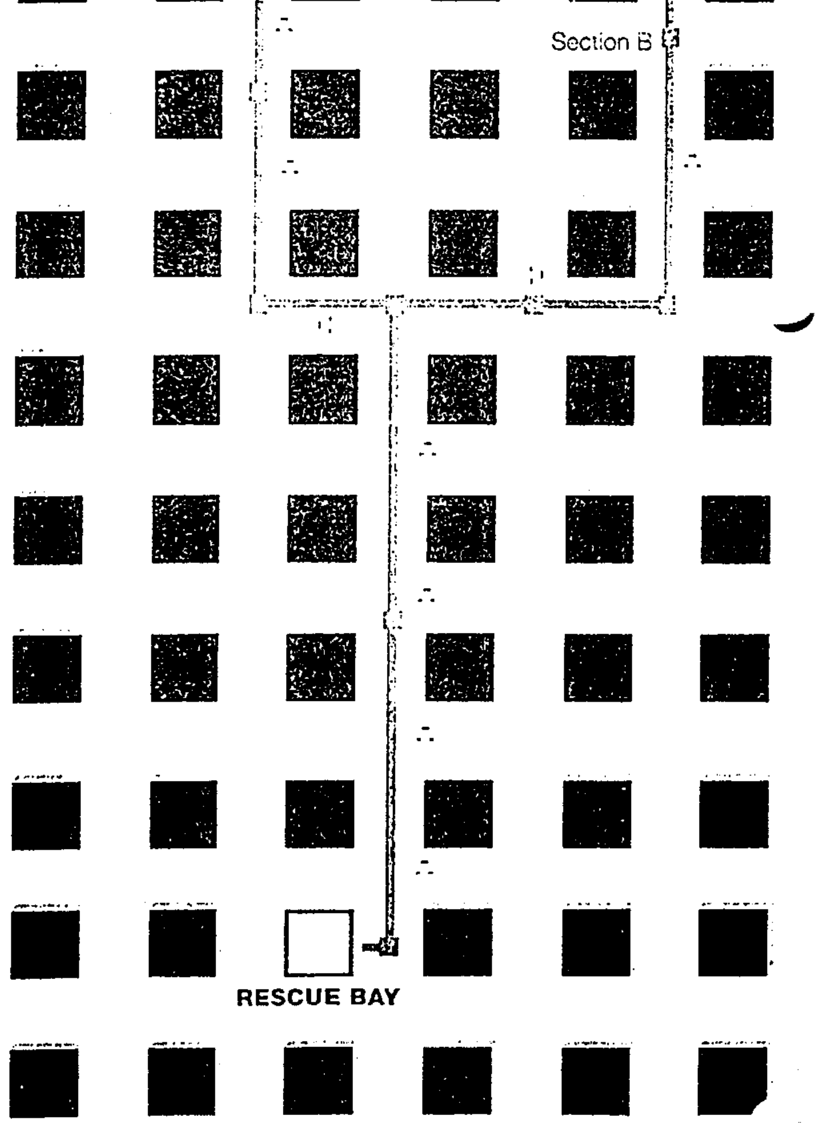

MOSES

I.A. M777/L277

MAINSFAIL OPERATED SOUND EVACUATION SYSTEM

The **MOSES** system is designed to guide personnel from the workplace underground to a safe area, such as the rescue bay. This is accomplished by a series of small, roof-mounted units, spaced at intervals of 50 m, which emit both an audible and visual signal in a cyclic routine.

The cycle commences at the working face and terminates at the rescue chamber.

It has already been proven that personnel can easily follow either the audible or visual signal to safety.

The duration of the cycle is easily preset at a control unit situated in the rescue bay. The MOSES system is triggered by any one of several sensors and will operate:-

In the event of a power failure:-

- By an analog signal from a smoke or carbon monoxide sensor.
- Input from a SCADA based system.
- Manually from any pre-determined local points.

Each **MOSES** unit is powered from a 220 V supply, and is provided with internal backup batteries capable of sustaining the operation for up to 18 hours. The **MOSES** system is designed to operate up to a maximum distance of 4 km from the control point.

APPENDIX II INFORMATION ON THE PARKERSCAPE SYSTEM

PARKERSCAPE

NECESSITY IS THE MOTHER OF INVENTION.

(ENGLISH PROVERB)

BY J.A.PARKER

For many years places of safety (Refuge Chambers) have been constructed underground to provide a safe place for workmen to retire to in the event of an occurrence that endanger life. Self Rescuers with a duration of about 30 minutes were introduced to enable workmen to retire safely to these places.

The major problem in finding these places in a exceptionally poor visibility. Over the past years how many times have we read investigation reports stating that workmen had failed to find these safe places and some instances walked passed them.

The question arises about the visual distance a flashing light can be seen in a exceptionally poor visibility and audible system becoming distorted in the underground environment.

Present systems in use e.g.. metal reflective arrows attached to electrical signal cable on conveyor belts , workmen are expected to cover a distance of 1 500 metres before the duration of their self rescuers has expired. Because of poor visibility time can be wasted by searching for arrows and workmen will be stumbling and falling and is possible that the self rescuer could expire before the workmen reach these safe places yet.

So hence the need for a system to enable workmen to travel at normal walking pace of about 5 kilometres per hour thus giving a range of 2 kilometres for the duration of the self rescuer.

The "PARKERSCAPE" system give you this and more the joints on the rail are of such that once you are "CLIPPED ON" with the attachment you can only freely travel in one direction. Mine Rescue Teams can travel in the other direction by lifting the attachment over the joints

Very little training is required and confidence builds up quickly enabling the user to walk much quicker than his normal rate to place of safety.

[illegible]

PSYCHOLOGICAL CONDITIONS AFTER AN UNDERGROUND EXPLOSION AND FIRE

FIRES

TOXIC & EXPLOSIVE GASES
SMOKE
POOR - NIL VISIBILITY
HEAT
FLAMES
POSSIBILITY OF
EXPLOSIONS,BAD ROOF
CONDITIONS & EFFECTED
ESCAPE ROUTES

EXPLOSION

TOXIC & EXPLOSIVE GASES
SMOKE
POOR - NIL VISIBILITY
HEAT
FLAMES
NO VENTILATION
BAD ROOF CONDITIONS
FALLS OF GROUND
DEBRIS IN ALL ROADWAYS
WALLS,DOORS,CONVEYOR
STRUCTURE & MACHINERY
STREWN OVER WIDE AREA

TEST RUN ON PARKERSCAPE
DATE : 7th. SEPTEMBER 1994

OBJECTIVES

TO ESTABLISH THE PERCENTAGE OF WORKERS WHO WOULD FIND THE ESCAPE ROUTE ONCE BLIND FOLDED.

RESULTS

ALL 20 BLIND FOLDED WORKERS FOUNDTHE PARKER RAIL.
MAXIMUM TIME TAKEN 4 MINUTES 14 SECONDS
MAXIMUM DISTANCE COVERED 90 METRES
AVERAGE TIME 2 MINUTES 28 SECONDS
AVERAGE DISTANCE 52 METRES
AVERAGE SPEED 21 METRES/MINUTE (1,2K.P.H)
AVERAGE SECTION WITH 13 ROADS OF
12m CENTRES

GREENSIDE COLLIERY

(PARKERSCAPE)

DOCUMENT 18

In the Matter of:)
)
PUBLIC HEARING ON MSHA'S)
EMERGENCY TEMPORARY STANDARD)
FOR EMERGENCY MINE EVACUATIONS)

Pages: 1 through 137

Place: Charleston, West Virginia

Date: May 9, 2006

DEPARTMENT OF LABOR
Mine Safety and Health Administration

In the Matter of:)
)
PUBLIC HEARING ON MSHA'S)
EMERGENCY TEMPORARY STANDARD)
FOR EMERGENCY MINE EVACUATIONS)

Marriott Town Center
200 Lee Street East
Charleston, West Virginia

Tuesday,
May 9, 2006

The hearing in the above-entitled matter was convened, pursuant to Notice, at 9:05 a.m.

BEFORE: Edward Sexauer,
Moderator

APPEARANCES:

DEBRA JANES
RON FORD
ROBERT SNASHALL
JEFFERY KRAVITZ
EDWARD SEXAUER
ERIC SHERER
TIM MACLEOD
KEN SPROUL

APPEARANCES (CONT'D)

SPEAKERS:

RON BOWERSOX
MARK COCHRAN
MIKE WRIGHT
TONY BUMBICO
DOUG CONAWAY
JOHN GALLICK
MARK ELLIS
CHRIS BRYAN
ERWIN CONRAD
JACK HENRY
ELIZABETH CHAMBERLIN
CHRIS HAMILTON
TIM BAKER
RICK ABRAHAM
JAMES SZALANKIEWICZ

P-R-O-C-E-E-D-I-N-G-S

(9:05 a.m.)

MR. SEXAUER: Good morning, my name is Edward Sexauer. I am the Chief of the Regulatory Development Division of the Office of Standards, Regulations, and Variances for the Mine Safety and Health Administration. I will be the moderator of this public hearing on MSHA's Emergency Temporary Standard for emergency mine evacuations.

At this moment, would you pause with me for a moment of silence in honor of the miners who lost their lives and who were injured at the Sago Mine explosion and the miners who lost their lives or were injured at the Aracoma Alma Number 1 Mine accident, and for all the miners who have lost their lives or have been injured this year, and for all the miners who have lost their lives and have been injured in this country since the beginning? So, if you will, pause with me for a moment.

(Moment of silence.)

Thank you. On behalf of the Secretary of Labor, Elaine Chao and David Dye, Acting Assistant Secretary of Labor for the Mine Safety and Health Administration, I want to welcome all of you here today. Also attending this public hearing are several individuals from MSHA who are on the committee drafting the rule. To my left, Eric Sherer, of Coal Mine Safety and Health Division and Chair of the subcommittee. On my right, Jeff Kravitz, Chief of the Mine Emergency Operations and Special Projects, Pittsburgh Safety and Health Technology Center. Tom MacLeod, Policy and Program Coordination Division, Educational Policy and Development. Ken Sproul, Quality Assurance Division, Approval and Certification Center. Robert Snashall from our Solicitor's Office. And, Debra Janes, Regulatory Specialist, in the back of the room right now, but she'll be joining us shortly. And, Ron Ford, Economist, from our office.

This is the fourth hearing on the emergency standard. The first hearing was held in Denver, Colorado, on April 24. The second was held in Lexington, Kentucky, on April 26. The third was held in Arlington, Virginia, on April 28. Copies of the Emergency Temporary Standard, the Federal Register notice that rescheduled this hearing from April 11 to May 9, and volumes I and II of the compliance guide are available on the table where you signed in your attendance.

The purpose of these hearings is to receive information from the public that would help us evaluate the requirements contained in the emergency standard and produce a final rule that promotes safety -- safe and effective evacuation of miners during mine emergencies. We also will use data and information gained from these hearings to help us craft a rule that responds to the needs and concerns of the mining public so that the provisions of the emergency standard can be implemented in the most effective and appropriate manner. We published the ETS in response to the grave danger to which miners are exposed during underground coal mine accidents. The ETS includes requirements in four areas. The first area, immediate accident notification, is applicable to all underground and surface mines, both coal and metal/nonmetal. The three other areas covered by the rule, self-contained self-rescuer storage and use, evacuation training, and installation and maintenance of lifelines apply only to underground coal mines. During these hearings, we are soliciting public input on these issues. The hearings give manufacturers, mine operators, miners, and their representatives, and other interested parties, an opportunity to present their views on these issues.

MSHA issued this emergency standard on March 9, 2006, in response to the tragic accidents at the Sago Mine on January 2 and the Aracoma Mine -- Alma No. 1 Mine on January 19. MSHA determined that better notification, safety, and training standards are necessary to further protect miners when a mine accident takes place.

The ETS was issued in accordance with section 101(b) of the Federal Mine Safety and Health Act of 1977, the Mine Act. Under section 101(b), the emergency standard is effective until superseded by a mandatory standard which is to be published no later than nine months after publication of the emergency standard. The emergency standard also serves as a proposed rule.

As stated earlier, we will use the information provided by you to help us decide how best to craft the final rule. In addition to the provisions of the emergency standard, we are also considering the following issues and seek further information from you. As you address these issues, either in your comments to us today or those you sent to us in Arlington, please be as specific as possible with respect to impact on miner safety and health, mining conditions, and the feasibility of implementation.

Some additional issues:

1. Should miners have the ability to tether themselves together during escape through smoke-filled environments? If so, what length of tether between miners should be required? Should a miner's tether be capable of clipping easily to another's so that any number of miners could be attached together to work their way out of the mine? How should the tether be attached to the miners' belts, or, should there be a place other than the miners' belts to attach the tether to the miners? Should the tether be constructed of durable and/or reflective material? Where should the tether be stored on the section, or could it be part of the miner's belt? Should it be stored with additional SCSRs in a readily accessible and identifiable location, or in a separate location?

2. Should a training record under new paragraph 75.1502(c)(3) not only include a requirement that miners -- mine operators certify, by name, all miners who participated in each emergency evacuation drill, but also include additional information, such as a checklist? The checklist could be used to itemize the successful completion of each step in the training, as outlined in the approved program of instruction.

3. When should a miner don an SCSR during an evacuation? Currently, miners are told to don an SCSR when they believe they are in danger or when smoke is encountered. This may leave miners vulnerable to irrespirable air, such as air that contains lethal carbon monoxide levels or low oxygen. MSHA is considering requiring that at least one miner in a group of miners, and an individual miner when working alone, have at least one multi-gas or air quality detector with them.

4. In the preamble to the ETS, we discussed a method to locate additional SCSRs based on a joint MSHA-NIOSH heart rate study. MSHA solicits comments on whether the heart rate method is the most appropriate method to determine location, whether it is realistic, and any other comments you may have.

What other reliable alternatives exist for determining where to position additional SCSRs in the mine?

5. MSHA is considering a requirement that additional SCSRs under new paragraph 75.1714-4(c) be stored in all escapeways in intervals of 5,000 for mines where the escapeway height is above 48 inches, and 2,500 feet for all other mines. Would such a specification standard be more appropriate than the performance-oriented heart-rate method provided in this ETS? Regarding such a specification standard, what would be appropriate: a 5,000 and 2,500 foot intervals for heights greater than 48 inches and heights of 48 inches or less, respectively? Or, some other specific interval?

6. Should all underground coal miners be required to use SCSRs exclusively? If so, is it appropriate to prohibit the use of filter self-rescuers in all underground coal mines? In addition, MSHA is considering adding a new provision to 75.1714-4 that would allow the use of new SCSR technology to comply with the standard, such as SCSRs that have the ability to provide up to two or more hours of oxygen per unit. Is such a provision appropriate?

7. Manufacturers sometimes lose track of which mines purchased their SCSRs. When a mine shuts down, the SCSRs are often sold to another mine. In the past, problems have been discovered with all brands of SCSRs. MSHA is considering requiring that the following information be reported for each SCSR at each mine: 1) the total number of SCSRs, 2) the manufacturer, 3) the model, 4) the date of manufacture, and 5) the serial number. Is it appropriate to require mine operators to report to the relevant MSHA District Manager the total number of SCSRs in use at each underground coal mine? If so, should any additional information be reported?

8. Because, in the past, MSHA did not always learn of problems associated with SCSRs, MSHA is considering a requirement that mine operators promptly report to the MSHA District Manager in writing all incidents where any SCSRs required by 75.1714, is used for an accident or emergency, and all instances where such SCSR devices do not function properly. In addition, where any SCSR device does not function properly, the mine operator would be required to retain the device for at least 90 days for investigation by MSHA. These requirements would help assure that MSHA is notified of problems in a timely manner so that MSHA can provide timely notice to both manufacturers and users to assure that the affected SCSRs are available for testing and evaluation. Should MSHA include such requirements in the final rule?

9. SCSR storage locations in escapeways may not be readily accessible to all persons underground, such as pumpers, outby crews, and examiners. Are there other ways to provide readily accessible SCSR coverage for these miners? Are there other storage locations that would be readily accessible to such persons?

10. MSHA sought comments on the appropriateness of requiring that signs to help locate SCSR storage areas be made of a reflective material. MSHA also asked whether there are alternative methods available for making SCSR storage locations easy to locate when conditions in the mine might obscure the storage location. What methods exist that would make SCSR storage locations readily visible?

11. Under new paragraph 75.1714-4(c), operators are required to have separate SCSR storage in each escapeway. Where a mine has parallel and adjacent escapeways, under what circumstances would it be appropriate to allow a hardened room or "safe haven" to serve both escapeways with one set of SCSRs? A hardened room is a room constructed with permanent seal techniques, submarine-type doors opening to both escapeways, and positive ventilation from the surface through a borehole. Is a safe haven an acceptable alternative? If so, what should be the minimum criteria for MSHA to accept a hardened room or safe haven?

12. Currently, cone systems on lifelines -- this is number 12. Cone systems of lifelines vary, some with the cones pointing toward the face, and others pointing away from the face. Miners may become confused in an emergency as to the direction of escape. Should cones or other directional indicators on lifelines be standardized? Following a NIOSH recommendation and for ease of movement, should the point end of the cone be toward the face?

13. Miners should be able to safely evacuate a mine without the use of mechanized transportation. There may be unique escapeway conditions, including ladders, mandoors, airlocks, and overcasts where hands-on experience of these

conditions is required in order to quickly and safely escape the mine. Is it reasonable to require that miners walk the escapeways at least under these unique escapeway conditions? Should all miners be required to walk the escapeway in it's entirety rather than use mechanized transportation during the drills required by new paragraph 75.1502(c)? We are considering including a requirement in the part 48 training program for new miners that new miners travel, at least in part, both escapeways. Would this training be appropriate, and should the training include walking out part or all of the escapeways?

14. A more instructive emergency evacuation practice may be provided by using realistic drills. For example, conducting a drill in smoke or using a realistic mouthpiece that provides the user with a sensation of actually breathing through an SCSR, commonly referred to as "expectations" training, are more realistic than simulation training. What other realistic emergency evacuation practices and scenarios would ensure that miners are better prepared to act quickly and safely in an emergency?

We intend that scenarios required by the Approved Program of Instruction under paragraph 75.1502(a) be used to initiate the drills and to conduct the mine emergency evacuation drills required by paragraph 75.1502(c). For example, to start a drill, the section foreman may chose one of the mines' approved explosion scenarios. The foreman would gather the miners on the section and state where the explosion occurred, any special circumstances of the event, and conditions requiring immediate donning of SCSRs. The foreman and miners would then physically follow the best options for evacuation as the evacuate the mine. When the miners travel to the place or into the conditions that require immediate SCSR donning, the need to don the SCSR must be made clear so that it is understood by all.

15. We expect that the scenarios developed as part of the mine emergency and firefighting program of instruction under new paragraph 75.1502(c) would be included as part of the emergency evacuation drills under new paragraph 75.1502(c), making the drills more realistic. Should we further clarify this issue in the final rule? Are there additional requirements that should be included in this training to make it more realistic, such as conducting SCSR donning in a smoke-filled environment?

16. We are considering putting all emergency evacuation drill requirements in 75.1502. Thus, for example, the escapeway drill requirements under existing 75.383 pertaining to the frequency of drills, how far miners travel in the drills, and the number of miners involved in each drill, would be incorporated into requirements under new 75.1502. Under paragraph 75.383(b)(1) each miner must participate in a "practice escapeway drill" at least once every 90 days, but it is only required to travel to the area where the split of air ventilating the working section intersects a main course -- main air course, or 2,000 feet outby the section loading point, whichever distance is greater. Under new 75.1502, during the emergency evacuation drills, the miner must travel to the surface or to the exits at the bottom of the shaft or slope. Existing paragraphs 75.383(b)(2) and (b)(3) require that "practice escape drills" occur at least once every six weeks, but only involve two miners and a supervisor. Miners systematically rotate in taking these drills so that eventually, all miners participate. Under new 75.1502, emergency evacuation drills are required for all miners and at periods of time not to exceed 90 days. We will have to reconcile these time differences.

MSHA is requesting comments on incorporating all evacuation drill requirements into 75.1502. we also are considering requiring section bosses to travel both escapeways in their entirety prior to acting as a boss on any working section or at any location where mechanized mining equipment is being installed or removed.

17. We are -- also are considering requiring that all mine fires be reported to MSHA, including fires shorter than 30 minutes duration. This would address all mine fire hazards, including situations where a number of short duration fires occur. Should the definition for "accident" in existing paragraph 50.2(h)(6) be revised to include all unplanned underground mine fires, or fires of a particular type or duration, or occurrences at particular locations in the mine?

To date, we have received two comments on this emergency standard. You can view these comments on our website at www.msha.gov under the section entitled "rules and regulations." We have also answered several questions on compliance with the ETS covering a range of issues. These questions and answers are included in the compliance guide that I referred to earlier and are posted on our web page.

Finally, we have received questions as to whether the emergency evacuation training provisions for metal and nonmetal mines are affected by the ETS. While the ETS amends part 48 by adding references to the requirements to the emergency evacuation plans in existing 57.11053 for underground metal and nonmetal mines, these references do not affect existing training requirements for metal and nonmetal miners and it is our intent not to change the existing part 48 emergency evacuation training provisions for metal and nonmetal mines. We will clarify this in the final rule.

The format for this public hearing will be as follows:

Formal rules of evidence do not apply, and this hearing will be conducted in an informal manner.

Those of you who have notified MSHA in advance of your intent to speak or who have signed up today to speak will make your presentations first. After all scheduled speakers have finished, others can request to speak.

We also have an attendance list and ask that you make sure that you sign it before you leave, if you haven't done so.

If you wish to present any written statements or information today, please clearly identify your material. When you give it to me, I will identify the material by the title as submitted. You may also submit comments following this public hearing. To be considered, they must be submitted to MSHA by May 30, 2006, which is the close of the comment period. Comments may be submitted by any of the foll -- any of the methods identified in the ETS. Again, we have copies of the ETS and the compliance guide in the back of the room and posted on our web page at www.msha.gov.

We will post the transcripts of the public hearings on our website. I believe that three -- the transcripts of the three previous hearings are already posted on our website. Each transcript, including this one, will be posted approximately one week from the completion of the hearing. The transcript will include the full text of the opening statement and any specific issues for which the Agency seeks additional comment.

We will begin with persons who have requested to speak. Please begin by clearly stating your name and organization for the record, to make certain we obtain an accurate record when you speak.

Our first speakers -- I believe we have two speakers that are going to speak together. Ron Bowersox, from the United Mine Workers of America, and Mark Cochran, also of the United Mine Workers of America.

MR. BOWERSOX: Good morning.

MR. SEXAUER: Good morning.

MR. BOWERSOX: Can you hear me okay?

My name is Ron Bowersox. I'm a safety representative with the United Mine Workers of America. I'd like to take the opportunity to thank the panel for me to speak here in regards to the Emergency Temporary Standards. I do believe there would be more participation from the mines, living in the Northern -- like, Western Washington, PA area, the Northern mines in West Virginia, PA, and Ohio. Those miners would be a lot easier to get to that area, because that is a long distance to travel with the long schedules those guys work now.

After receiving the final review and reading it, it's clear there are issues that have existed for over 20-plus years. Examples from the Register, 1984, 27 miners lost their lives in a fire at the Wilberg Mine. 1990, 18 miners escaped from a fire at the Matthews Mine. Only seven miners donned their SCSRs at their first sign of smoke. 1998, two miners, during the escape from the Willow Creek Mine fire, miners that used the SCSRs had difficulty starting the oxygen flow. Bottom line, 20-plus years later, we're sitting here in Charleston, West Virginia, discussing the things that should have already been taken care of.

I would like -- I would hope the Mine Safety and Health Administration acts quickly and takes action that protects miners when they must evacuate a mine after an emergency occurs.

I have concerns about the current practice of permitting mine fires that last less than 30 minutes to go unreported. This should be eliminated. Far too often, such events occur over and over because once a fire is extinguished within 30 minutes, the operator is not compelled to eliminate the source of the problem. This reporting, I feel, with all mine fires, will eliminate many of these hazards in the industry.

I believe the 15-minute notification must be strictly enforced. Two hours, like at the Sago Mine, is unacceptable. Fast notification, the faster response time to mine site for mine rescue teams, federal, state, union, and any others involved in mine rescue. Timing is everything in a rescue mission.

I think lifelines are needed to be -- they need to be flame-resistant. All cones should be faced toward the face area. This would be standardized with less confusion.

The -- in closing, there is a lot of new technology available. A few weeks ago, I was in Wheeling, West Virginia, and there was over 100 vendors there. They had communication tracking devices, new chambers, and I just feel we all need to work together to make our mines safer for our miners to return home, and our miners are our most precious resource. Thank you.

MR. SEXAUER: Ron, thank you.

MR. COCHRAN: My name is Mark Cochran, United Mine Workers of America Local 9909. I work at the Loveridge Mine, CONSOL Energy.

I want to speak a little bit here. Some of my thoughts are about the same as Ron's here, but the reason -- one thing I have is response time. The length of time it takes to get chromatograph machines and stuff to mount in sites to analyze air samples, hours can be lost not having machinery readily available to support mine rescue teams. Many times, the only equipment available is hand-held detectors. This is not capable of detecting or differentiating between a lot of the mine gasses and hydrocarbons which are given off during a mine fire or explosion.

Also, I'd like to see seismograph machinery located in areas where they can be put to use quickly and efficiently in the field to aid the search for mine -- trapped miners.

I've also heard statements about the 15 minute rule for reporting being too short a time. I personally feel that this is more than enough time and that it would help to get the people into the -- backup people in as quickly as possible, even in an unknown emergency situation. If there's a reasonable cause to think there is an emergency, time is of the essence.

Also, I've been around a lot of mine rescue teams and stuff, and it is recognized that mine rescue rules change depending on emergency situations at each mines. Specific guidelines are not always followed but must -- we must protect the rescuer.

All mines need to have mine rescue teams and some, depending on the amount of workers, could have at least two teams available. This would or is better to have an employee working at the mines and a mine rescue team that is familiar with their mines. They know the locations of most areas and the conditions at the mines. This would save a lot of valuable time.

Again, speaking of the two hour response time by the teams that are contracted out to the different mines, there's a lot of valuable time lost in emergency situations.

It could also prove very valuable to have mine rescue supply stations underground where material could be accessed by the teams as they advance, rather than waiting for supplies from the outside to arrive.

Self-contained self-rescuers used in the storage plans to be placed on the sections or long-haulage belt lines or other locations, I feel, should be checked as part of the mine examiner's run. Along with this, I'd personally like to see dates, times, and initials placed at the different caches and also be recorded in a book on the surface. This would ensure us that the self-contained self-rescuers are being checked properly and are also stored in their necessary locations.

And, to speak about part 50, the 30 minute rule, as Ron spoke about here, to me, it is very necessary to bring this -- bring an emergency as a fire out sooner. A fire that's burning for 30 minutes, at least in the Pittsburgh scene, is totally out of control by the time -- you know, I've been around Loveridge Mines. We've lost the mines twice up there due to mine fires and got it back up and everything, but 30 minutes is just entirely too long to report a mine fire.

And also, speaking about the rescue chambers. It could be beneficial in some circumstances, such as at the Sago Mines. From this disaster, we can all say that there must be an air supply that would sustain oxygen for a long period of time, at least a 48 to 60 hour minimum. This would need to be also large enough to support a section crew and located where they could be readily available.

Also, there needs to be the thought of the outby workers who may also be trapped in -- on the beltlines, and et cetera. Thank you.

MR. SEXAUER: Let me just reiterate the Agency's position that during a mine emergency, the first response to be to evacuate the mine. You're addressing mine rescue chambers, and, you know, that barricading in the mine would be the last resort and defense. That's the way we look at it.

MR. COCHRAN: I agree with you 100 percent on that. I was in the Sago Mines, part of the investigation, and that would be a very last resort. I don't know that I would ever barricade, personally.

MR. SEXAUER: Okay. Any questions? Gentlemen, thank you.

Are we picking up the sound from that second mic? Can you hear in the back? You can? Okay.

Our next speaker will be Mike Wright.

MR. WRIGHT: Thank you, Mr. Sexauer.

My name is Mike Wright. I'm the Director of Health, Safety, and Environment for the United Steel Workers. We're a union that represents 850,000 workers in North America, including the majority of unionized metal and nonmetal miners in the United States and Canada. We also represent a significant number of coal miners in Canada.

And, as I was walking over here this morning, I remembered that today is the 14th anniversary of the worst mining disaster in recent Canadian history, that was the underground explosion and fire at the Westray Mine in Nova Scotia, which killed 26 miners. We were in the middle of an organizing campaign when that happened, and we continued that campaign, even though the mine never reopened, and continued to represent those families. One of the things that came out of that disaster was a law across all of Canada making killing through corporate negligence a crime punishable by prison. I hope we can achieve that, some day, in this country.

This hearing is focused exclusively on coal mine safety and health, and that's appropriate. I'm sorry, almost exclusively on coal mine safety and health, and that's appropriate, given the tragedies of Sago and other coal mines so far this year. Our union doesn't represent coal mines in the United States -- coal miners. You might ask why I'm here. It's really for three reasons: the first is to demonstrate our support for the families of the Sago miners and all the other victims and for our sister union, indeed, our parent union, the United Mine Workers of America; second, to strongly support the one part of the ETS that applies to metal and nonmetal mines, the requirement that MSHA be notified of accidents within 15 minutes; third, to urge MSHA not to forget about metal and nonmetal miners as it moves forward to develop, hopefully, stronger requirements for mine evacuations, rescue, and refuge.

Let me start with the immediate notification of mine accidents. I've been involved in too many rulemakings, both OSHA and MSHA, to be very surprised about arguments coming from mine operators or other employers, but I must say they had to reach to come up with objections to the 15 minute rule. I've read a lot of those in the transcript.

They include things like "calling MSHA might interfere with a rescue." Well, you'd better look at your rescue plan if it's going to be disrupted by having to make a single phone call. Or, "there may be only one phone line and we need it to call 911." Well, if that's the case, buy yourself a cell phone or a Blackberry or use the one you probably already have, like the majority of Americans. And, if you don't get a good signal where you are, I'm sure your local service provider will be happy to install a second line. Or, "we're really not sure there's been an accident until we investigate." Well, call anyway. You're not going to get cited by MSHA because the situation turned out to be less serious than you originally thought.

In short, the 15 minute rule makes very good sense, and MSHA should stick to it in the final rule. And, by the way, the miners' rep ought to be immediately notified as well, and the regulation ought to state that explicitly.

I do have to congratulate MSHA for the fact that it appears to be enforcing the 15 minute rule. We had a fire at the Carmeuse Limestone Mine in, I believe, Kentucky, back on April 10, and that mine was cited under part 50 section 10 because they did not notify the Agency in the prescribed time limit.

Let me now turn to other aspects of this ETS and other regulations that should be applied, not just in coal mines, but in all underground mines, but I want to make it clear that nothing the USW proposes is meant to delay effective action in coal mines. We are aware that MSHA would need additional rulemaking to extend other provisions of the ETS beyond coal, therefore, we urge the Agency to finalize this rule as quickly as possible. You can take less than the nine month statutory limit. That would be great. And then, turn it's attention to metal/nonmetal mines as part of a comprehensive regulatory process involving escape, rescue, and refuge in all underground mines.

Most of the deaths this year have occurred in coal mines, and the ETS is especially concerned with coal mine fires, but we should remember that the worst mining disaster in the United States in the last 35 years happened in an underground metal mine and it was a fire. Of course, the fire was at the Sunshine Silver Mine in Kellogg, Idaho, on May 2, 1972. Ninety-one miners died, all from carbon monoxide poisoning. Incidentally, those miners had filter self-rescuers. They didn't work. They were exposed to too much carbon monoxide.

Sunshine was one factor leading to the Mine Safety and Health Act itself, and many of the regulations promulgated under the Mine Safety and Health Act have made such fires far less likely. But, 45 percent of the mine fires reported to MSHA between 1991 and 2000 occurred in metal/nonmetal mines. There are plenty of combustible materials in metal/nonmetal mines. Fuels for mobile equipment and mobile equipment itself, old timers, belts, methane, combustible ores like gilsonite, and other materials. A January fire in a Saskatchewan potash mine forced 72 miners into a refuge chamber for 28 hours because of toxic gasses and smoke started in some plastic piping. Potash, as you know, doesn't burn. There are plenty of ignition sources, as well. Electrical sparking, belt friction, cutting and welding, even spontaneous combustion. And, of course, there are reasons other than a fire for evacuating a mine, including, for example, flooding.

There is no good reasons why the lifelines required for underground coal mines should not also be required in metal/nonmetal mines, and there is certainly no good reason not to even give notice on this issue in the Federal Register and thereby making it impossible for MSHA to require lifelines without -- in metal/nonmetal mines without new rulemaking.

Obviously, the provisions for extra self-contained self-rescuers will not apply because SCSRs are not required in metal/nonmetal mines in the first place; however, they should be required in at least some metal/nonmetal mines. There was a proposal to do that on MSHA's regulatory agenda in 2001. SCSRs would have been required in high-risk mines, specifically, gassy mines, and some others. That proposal was withdrawn by the current administration. We believe it should be reinstated immediately.

That concludes my comments. Thank you for the opportunity to testify this morning.

MR. SEXAUER: Any questions? Mr. Wright, thank you very much.

MR. WRIGHT: Thank you.

MR. SEXAUER: Our next speaker will be Tony Bumbico from Arch Coal.

MR. BUMBICO: Good morning.

MR. SEXAUER: Good morning.

MR. BUMBICO: My name is Tony Bumbico. That's spelled B-U-M-B-I-C-O. I'm the Vice President of Safety for Arch Coal.

Arch is the second-largest coal producer in the United States. Our corporate office is in St. Louis, Missouri. Arch and it's subsidiary companies have over 3,500 employees and we operate mines in Colorado, Kentucky, Utah, Virginia, West Virginia, and Wyoming. With me is Doug Conaway. Doug is the Corporate Safety Director for Arch.

We're here today in response to the Mine Safety and Health Administrations request for comments on the Emergency Temporary Standard published on March 9, 2006, which contains regulations relevant to mine emergency evacuation. Our comments will be offered in two parts. I will discuss Arch's general position on the ETS. Following my comments, Doug will respond to some of the specific questions posed by MSHA in their opening comments.

Our comments today reflect support by Arch of the testimony presented by the National Mining Association at the April 28, 2006, hearing held in Arlington, Virginia. In addition, our testimony will express concerns that are specific to our operations. We appreciate the opportunity to comment and hope that our comments will assist MSHA in future decisions related to the subject.

Arch supports the intent of the ETS. The objective of this regulatory initiative is to protect miners from grave dangers they face when they must evacuate a mine after an emergency occurs. Similar to other responsible operators, we are committed to continuously improving health and safety at our mines.

In particular, we support the Agency's overall efforts to address several key issues related to self-escape and aided rescue that were factors at the Sago and Alma tragedies. We extend our sympathies to the families of the Sago and Alma miners and the other miners who have lost their lives this year.

As a company, Arch is committed to learn from these events. We continue to emphasize to our employees that self-escape is preferable to barricading when confronted with an emergency. In addition, we stand ready to work with MSHA and other responsible parties to improve the ability of miners to escape when a disaster occurs.

Our initial comments are on training, part 48. In general, Arch supports the revised part 48 training requirements. In this area, we have two concerns.

The first relates to how these training requirements apply to visitors of mines, mines, in particular, that have multiple types of self-contained self-rescuers. In our opinion, requiring visitors who are unfamiliar with mining to don multiple SCSR units could prove confusing. We encourage MSHA to consider a more flexible approach in this area. Such an approach might focus on donning the principal SCSR unit assigned to the visitor, and using alternative types of training on supplemental SCSR units. An approach of this type might prove to be less confusing to visitors.

We have a similar concern with regard to SCSR training for certain types of independent contractors. As you're aware, some contractors are exposed to mine hazards on a regular and continuing basis. We feel that contractors in this category should receive the same type of SCSR training as miners. On the other hand, many contractors are only exposed to mine hazards on an infrequent and intermittent basis. In our opinion, contractors in this category should receive a level of SCSR training similar to the training provided to visitors. We encourage MSHA to consider these SCSR training concerns when drafting the final rule.

Notification, part 50. The accident reporting revisions incorporated in the ETS are intended to facilitate rapid response by MSHA to serious mining accidents. Arch strongly supports this objective. We agree with the need to notify MSHA promptly to assist mine operators in dealing with mine emergencies. When accidents occur that threaten the safety of coal miners, a rapid emergency response is appropriate and essential.

In life threatening situations, or situations requiring potential rescue and recovery response, it is essential to immediately dispatch emergency resources to the accident scene. While we agree with the intent of the ETS, we maintain that many of the immediately reportable accidents requiring 15 minute notification do not justify a rapid response. As a result, we recommend the development of a rapid response notification system that requires notification of response proportional to the nature of the accident.

The ETS requires that all immediately reportable accidents that occur on mine property, as defined by 30 CFR 50.2 be reported by the mine operator to MSHA within 15 minutes. Clearly, many of the events defined as immediately reportable should require a mine operator to notify MSHA within the prescribed 15 minutes. We contend, however, that each event must be evaluated on it's own merits. It makes no sense to contact MSHA within 15 minutes when the health and safety of miners is not at risk.

In 2005, MSHA was notified of approximately 2,400 immediately reportable accidents. Approximately 90 percent of these 2,400 incidents did not involve an injury to a miner. They involved accidents in two categories, unplanned roof falls at or above the anchorage point and damage to hoisting equipment that interferes with it's use for more than 30 minutes.

Currently, MSHA documents the fact that they were notified of accidents that fall in these two categories. An MSHA inspector may visit the mine site to conduct a follow-up investigation into these nonemergency events. The Agency follows up according to the seriousness of the accident reported. If an inspector does conduct a follow-up inspection related to these non-life threatening types of accidents that may occur a day or two after the accident is reported, it would be counterproductive to contact MSHA within the required 15 minute time frame for these nonemergency events. It is not necessary to activate mine rescue personnel and local emergency response resources for all immediately-reportable accidents. Early notification and rapid response should be in proportion to the seriousness of the accident.

In our opinion, immediately reportable accident trends indicate that no benefit will be derived from early notification or rapid response for these types of non-emergency, non-injury events. The 15 minute notification period required by the ETS should be reserved for fatalities, serious injuries, and accidents with the potential to require a mine rescue or recovery response.

The ETS is solely focused on the 15 minute notification requirement following an immediately reportable accident. What the ETS fails to address is how MSHA will receive and responds to these notification calls. We are concerned that this omission will result in a system that unnecessarily delays effective emergency response.

The current protocol requires a mine operator to call their MSHA district office when an immediately-reportable accident occurs. If that call is placed outside of business hours, the caller is forwarded to an answering service. The answering service provides the mine operator with numbers to call to personally reach MSHA district officials. If the caller can't reach one of these individuals, he or she is expected to contact the MSHA headquarters.

The MSHA notification protocol has built-in time delays. It requires mine operators to place multiple calls at a time when they should be focusing on responding to the emergency event. MSHA needs to eliminate their system of transferring calls and using answering machines to advise callers of other emergency response numbers.

In an emergency, each additional call that a mine operator has to make consumes precious time. MSHA should consider streamlining the process.

One method of making this system more efficient would be for MSHA to implement a protocol requiring operators to make a single call to an 800 number to notify the Agency of an accident. As an alternative, MSHA could consider a system in which each MSHA district would provide mine operators with a list of emergency contact numbers. In addition, MSHA could assign staff to be on call to receive emergency calls.

A mine operator should only be required to place one call to a designated person when an emergency occurs. That individual should have the ability to determine the severity of the situation and the authority to direct an appropriate response. A notification system of this type would eliminate the built-in delays created by the current accident reporting protocol.

Part 75. Similar to the proposed changes in part 50, the revisions proposed under part 75 are intended to address legitimate concerns related to self-escape during a mine emergency. Arch agrees with many of these concepts contained in part 75 of the ETS. We're concerned, however, that practical application of some provisions of part 75 may be counterproductive and difficult to achieve.

Section 75.387(i). Arch supports the use of lifelines in escapeways as a means of facilitating self-escape. Research indicates that lifelines can be a significant aid to miners in an emergency situation, in particular, when they encounter smoke -- a smoke-filled environment. In fact, Arch's underground mines were using lifelines prior to the effective date of the ETS.

We have concerns, however, about the practicality of installing lifelines in main travelways. In some situations, the installation of lifelines in the travel -- in travelways creates a potential hazard. This is especially true when the mine uses trolley power to power haulage equipment. We also believe that lifelines installed in the main travelways of mines using diesel equipment will be very difficult to maintain.

To date, we have not identified an effective method to install lifelines in the main travelways of our underground mines. In our opinion, there is no good way to install a lifeline in travelways that would be both accessible to miners and protected from heavy equipment.

In most instances, miners will use a mantrip or similar vehicle to exit the mine via the travelway in an emergency situation. In these situations, a lifeline would not be used. As a result, we recommend that MSHA reconsider it's position on requiring lifelines in escapeways that also serve as the main travelway of an underground mine. Or, as an alternative, the Agency should assist industry in developing appropriate methods to safely install and maintain lifelines in these areas of the mine.

75.1502(c)(1). Arch agrees with most aspects of the fire drill training requirements contained in 75.1502(c)(1). In particular, we agree with the emphasis on scenario training. Training of this type will help improve the problem solving and decision making skills of miners that are so critical during a mine emergency. We recommend, however, that MSHA revise the requirement to conduct fire drill training and mine emergency training every 90 days. In lieu of the 90 day requirement, we suggest that the training interval be modified to once each quarter. This change would not impact the quality of training. It would, however, provide more flexibility to large mines to accomplish the training in a more efficient manner. Most of Arch's underground mines are large complexes. Trying to schedule 300 to 500 miners for training on SCSR transfers, escapeway systems, firefighting, and evacuation drills would be difficult to achieve. We can accomplish this important task more effectively on a quarterly basis. This added flexibility will enable us to schedule crews for training on a systematic basis. It would also help to address scheduling complicated by vacations and absenteeism. If MSHA is concerned that a person would be trained at the end of one quarter and the beginning of the next, the Agency could require that the training be accomplished during a window of time as proposed by the operator's plan.

75.1502(c)(2). Arch opposes requiring all miners to walk the entire escapeway every 90 days. We do not believe that physically traveling the entire escapeway adds to the quality of the training. In some cases, it may pose a hazard to the miners. We do believe that miners need to receive additional training on a quarterly basis that covers the location of escapeway entrances from the workplace, the location of lifeline systems, the location of SCSR caches, the unique physical escapeway characteristics, and the location where important escape decisions will be made.

As stated during previous hearings on the ETS, MSHA needs to recognize that the coal industry has an aging workforce. The average age of our workforce is in the early- to mid-50s. In some circumstances, walking escapeways could pose an unnecessary risk, illness, or injury to these individuals.

As a result, Arch recommends that MSHA revise the proposed evacuation drill requirements. Miners should be permitted to travel their escape routes in vehicles or walk short distances to the ventilation split where self-escape decision making training could be conducted. In our opinion, this change would enhance training and allow for training on unique escapeway conditions and cover important topics such as the location of lifelines and SCSR caches.

75.1502(c)(2)(2). Arch supports the use of hands-on training with respect to donning and transferring SCSR units. This type of training is effective and necessary to familiarize miners with the proper procedure for utilizing self-contained self-rescuers. In our opinion, however, SCSR training can be accomplished more effectively in a controlled environment on the surface as opposed to underground. We support the Agency's recognition of this as reflected in the Emergency Temporary Compliance Guide. We suggest, however, that the training requirement for transferring SCSR units be modified with respect to operations that have multiple types of SCSR units. We propose that MSHA consider a training system that permits operators to alternate transfer training for different types of SCSR units on a quarterly basis. In essence, we're recommending that mines with multiple types of SCSR units be required to train on one type of transfer each quarter.

75.1714-2 and -4. With respect to the signage requirement for SCSR caches, Arch feels that the regulatory language is too restrictive. The term "SCSR" is an industry-wide term. It is used throughout the ETS. Section 75.1714(2)(f), however, requires the word "self-rescuer" or "self-rescuers" to be used on storage cache signs. It serves no useful purpose to require mines with existing SCSR storage location signs to install signs stating "self-rescuer." We recommend that the Agency reconsider their position and permit the use of the term "SCSR" for storage caches.

SCSR storage in the primary and alternative escapeway. Section 75.1714-4(c) requires additional SCSR storage in the primary and alternate escapeway to augment other SCSR requirements of the ETS. A number of companies have proposed the use of airlocks located between adjacent escapeways for storage of SCSR units. The use of an airlock has the additional benefit of providing employees with an area isolated from the main air course for the transfer of SCSR units. It could also be used to store other emergency supplies. Another alternative proposal would be to build an SCSR storage unit into a stopping to permit stored SCSR units to be accessed from either escapeway. Both of these proposals make practical sense. In MSHA's Emergency Temporary Compliance Guide, the Agency rejected this concept. We remind the agency that section 75.1714-4(c) does not require identical quantities of SCSR units be stored in both the primary and alternate escapeway. It requires additional units in the primary and alternate escapeway. The concept outlined above is practical. It would place supplemental SCSR units in locations that satisfy both primary and alternate escapeway storage. We are requesting that MSHA reconsider it's position on this subject.

MSHA also requested comments on the appropriateness of using a hardened room or safe haven for storage of SCSR units. According to MSHA, a storage room of this type would have positive ventilation from the surface through a borehole. My colleague, Doug Conaway, will address this question in more detail. The related issue I wish to address concerns surface rights and the practical means of gaining access to surface areas in order to drill boreholes. Many operations, particularly in the Western states, are mining under significant cover, which, at times, exceeds 2,000 feet. The surface rights for many of these mines are controlled by the federal government. Gaining access to surface areas at these operations to drill boreholes or install communication equipment is not an easy task. It is a task complicated by regulations, a lack of access roads, rugged terrain, and difficult weather conditions. If the Agency intends to require the installation of additional boreholes or the installation of communication systems on the surface, they need to consider this factor. The industry needs a more efficient means of accessing surface rights for emergency response and other safety-related purposes. MSHA is encouraged to take this factor into consideration when formulating the final rule.

In closing, I want to thank you for the opportunity to comment on the ETS. At this point, Mr. Conaway will address some of the specific questions mentioned in the ETS and in the Agency's opening comments, after which, we'll be able to able to respond to questions.

MR. CONAWAY: Good morning. My name is Doug Conaway. I am the corporate Safety Director for Arch Coal. I --

MR. SEXAUER: Excuse me, Mr. Conaway. That -- we're going to try another microphone setup, here, and see if this works a little better.

MR. CONAWAY: I appreciate the opportunity to comment on the Emergency Temporary Standard published by the Mine Safety and Health Administration on March 9, 2006. My specific purpose today is to offer testimony on some of the specific questions offered by MSHA relating to the ETS. MSHA has asked interested parties to respond to specific questions. I will proceed by stating the question, followed by the response.

Should miners have the ability to tether themselves together during escape through smoke-filled environment? Arch does not feel that tethering should be a requirement. We do feel that miners should have the option to tether and that the necessary equipment to tether should be available to miners. Miners faced with an emergency situation must have the flexibility to exercise judgment as to the best means for all persons to exit the mine in a safe manner. Each emergency has a unique set of conditions that must be evaluated prior to evacuating the mine. We have to rely on the problem solving and decision making skills of the miners in that situation to analyze their circumstances and exercise good judgment.

Storing a tether rope on a working section at the SCSR storage location would provide miners the option of tethering if they determine a need to link themselves together. It is not necessary to mandate every detail of the tether rope. This should be a performance-oriented issue. Any related regulation should specify that the tether be made of durable material of reasonable length and easy to attach.

Should a training record under new paragraph (c)(3) of 75.1502 include additional information, such as a checklist? Arch agrees that developing performance-based checklists that identify self-escape competencies would be a valuable tool to evaluate the proficiency of miners.

When should a miner don an SCSR during an evacuation? Should at least one miner in a group of miners or an individual miner working alone have a multi-gas or quality air detector? Arch feels that a regulation requiring that an individual miner or one miner in a group of miners to carry a multi-gas detector makes common sense. This would enable miners in an emergency situation to determine with more accuracy when to don an SCSR. If miners wait until they see the first evidence of smoke, it may be too late.

Should SCSR storage locations be determined by the performance-oriented NIOSH-MSHA heart rate study, or should specific distances, such as 2,500 and 5,000 feet, depending on seam height, be specified by the regulation? Arch does not feel that a prescriptive approach to SCSR storage locations is appropriate. Operators should be permitted to determine where caches are located based on the recommended test in the ETS. We agree with the general approach outlined in the MSHA-NIOSH heart rate study. In our opinion, a performance-oriented approach to the location of SCSR storage caches is more appropriate. Some states have adopted a standard which establishes SCSR storage locations by intervals based on the height of the coal seam. We also agree that this type of approach to locating SCSR storage caches, a performance-oriented standard of this type is easily understood and implemented. The travel time necessary to exit a mine varies considerably according to a mine's seam height, other unique physical characteristics, as well as the physical condition of the miners involved in the evacuation. Locating SCSR storage caches according to preset distances fails to address these variables. Finally, we agree with the Agency's criteria for approving SCSR storage plans should consider the materially different quantities of available oxygens provided by competing types of SCSR units. As the Agency is aware, some types of SCSR units are capable of providing emergency air far beyond the one hour rating capacity.

Should filter SCSR units be prohibited by the regulation? Arch feels that filter-type rescuers should be permitted under approved storage plans, specifically on long wall faces, where facing -- where space and clearance is very limited. Filter-type rescuers have historically been proven serviceable. They provide mine-worthy protection against hazardous levels of carbon monoxide. While many miners -- mines have voluntarily eliminated filter-type rescuers, operators should still have the option to continue using filter-type rescuers to supplement the one-hour SCSR units required by the ETS.

Should MSHA add a new provision to 75.1714-4 to allow the use of new SCSR technology that may provide up to two hours or more of oxygen? Our response to this question is a very straightforward yes.

Should MSHA require the following information to be reported for each SCSR at the mine: One, the number of SCSR units; two, the manufacturer; three, the model; four, the date of the manufacture; and five, the serial number? This information is already a requirement for mines with SCSR storage plans. These plans include the number and location of the SCSR units. If the locations change, the plans have to be updated. This provision would not require any additional information-gathering for mines with storage plans. While a requirement of this type would facilitate research-oriented data gathering and enhance potential recall efforts, the Agency first needs to arrive at a mechanism such as a barcode to facilitate data gathering. Even with a barcode, an additional reporting requirement of this type would be time consuming. While we agree with the information -- we agree that the information should be available at the mine, we disagree with the need for additional reporting requirements.

Should MSHA require mine operators to promptly report to the District Manager incidents where the SCSR unit used in an accident or emergency and all incidents where a SCSR malfunctions? Arch has no objection notifying the Agency when an SCSR unit used in an accident or emergency fails. We also agree with the need to provide MSHA access to units that failed during emergency use. We maintain, however, that the Agency should permit operators to participate in any testing and share test results. We see no value in notifying the Agency when SCSR units are routinely damaged or malfunction, unless there's a pattern of damage indicative of a product defect.

Are there other ways to provide SCSR storage locations for outby crews, pumpers, and examiners? If outby crews, pumpers, and examiners are not able to access the section escapeway SCSR storage caches within the allotted timeframe established for their mine, SCSR coverage consideration should be given to them on an individual basis. Pumpers and examiners are miners that work routinely in the same well-defined area of the mine. Utilizing the time-distance tables, SCSRs could be placed at the necessary locations to provide adequate coverage. Outby crews such as belt maintenance, supply personnel, et cetera, require transportation. These miners could use the SCSRs that are required to be stored on all mantrips that enter and exit the mine.

Where a mine has adjacent and parallel escapeways, under what condition should MSHA allow a hardened room or safe haven to be used to store SCSR units for both escapeways? A hard room is constructed with permanent seal techniques, submarine-type doors that open to both escapeways, and has positive ventilation to the surface. Based on the language of the ETS, a number of operators have proposed, as an alternative, the use of airlocks located between adjacent escapeways for the storage of SCSR units. A storage location of this type could also house other important emergency supplies. The use of an airlock has the additional benefit of providing employees with an area isolated from a main air course for which to transfer SCSR units. Another alternative proposal is to build an SCSR storage unit into the stopping to permanently store SCSR units to be accessed from either escapeway. Arch agrees with these concepts. Both proposals are simple, functional, and can be engineered in a safe, mine-worthy manner. Arch also maintains that an airlock can be engineered so that SCSR units are readily accessible. This might be accomplished by installing a larger door in the stoppings. We do not believe that it is necessary for an SCSR storage location of this type to be a hardened room with submarine doors and a borehole to the surface, as proposed in the Agency's opening comments.

Should the placement of directional cones be standardized according to NIOSH recommendation? Arch maintains that the placement of directional cones should be standardized according to the NIOSH recommendation. Having one standard method of installing directional cones will avoid confusion for miners who transfer from one mine location to another.

Should miners be required to walk the escapeway in it's entirety rather than use mechanized transportation? Should miners be required to walk a portion of the escapeway that contains unique characteristics? As stated in our general comments, Arch disagrees with the need to physically walk the entire escapeway. Miners can be familiarized with the general and unique characteristics of the escape route if they use mechanized transportation to travel this entry. We propose that the escapeway drill be devoted to more meaningful scenarios and expectations training in order to improve critical, problem solving, and decision making skills.

Should more realistic escape training be considered, such as smoke drills and expectations training, such as breathing through an SCSR? As stated in response to the previous question, Arch agrees that training of this type would be more meaningful than walking the entire escapeway.

Should all emergency evacuation drill requirements be included in 75.1502? We agree that the inclusion of all emergency evacuation drill requirements in one section would help clarify this section.

Should a new section foreman be required to travel both escapeways prior to acting as a boss on a section? This is a requirement that makes good practical sense. All supervisors should be familiar with the escapeway prior to assuming responsibility of working on that section. Those individuals who are currently supervising and working on a section should be grandfathered.

Should all mine fires be reported to MSHA, including mines shorter than a 30 minute duration? Arch maintains there is no compelling evidence justifying a revision in a definition of an immediately reportable fire. Current regulations require a mine operator to report an unplanned mine fire that is not extinguished within 30 minutes of discovery. Historically, this 30 minute period has provided mine operators with an adequate period to extinguish and control an unplanned heating event. To shorten the 30 minute period would result in numerous false alarms. It would also lead to the inefficient use of emergency response resources. The existing requirement in this area is clear. Mine operators understand what types of unplanned fires to report and what circumstance that requires MSHA notification. While there will always be unique circumstances that require a mine operator to exercise good judgment, changing the current requirement will only result in confusion. It will also result in numerous unnecessary phone calls. The current requirement for notifying MSHA of unplanned fires after 30 minutes is effective. It should not be changed.

Thank you for the opportunity comment. We will be available to respond to any questions you may have.

MR. SEXAUER: Gentlemen, would you be willing to leave a copy of your written comments with us? Thank you.

Excuse me, I think we have a question or two, here. I'm sorry.

MR. SHERER: Mr. Bumbico and Mr. Conaway, how many of Arch's mines have parallel entries to the haulageways that you were concerned about, as far as lifelines?

MR. BUMBICO: A pretty common concerns of all of our underground mines.

MR. SHERER: No, I mean, how many of your mines have parallel entries to those haulageways? Do you just have single haulageway entries that are on a separate split?

MR. BUMBICO: Well, a number of our mines in the West are two-entry mines, so we're operating on that type of a system, and I could get you some specific information in writing as to what we have.

MR. SHERER: Okay. There's no requirement that the escapeway be in the haulageway if you have a parallel entry.

MR. BUMBICO: We understand that.

MR. SHERER: Okay. Another question, you talk about using airlock doors for the storage of SCSRs. How would you propose to ventilate those areas?

MR. CONAWAY: Well, current airlocks are not ventilated -- I mean, they don't have a separate split of ventilation in the mine environment today, but you could, similar to ventilating a charger of sorts, you could provide some form of ventilation into that airlock.

MR. SHERER: So, you would ventilate it from the primary escapeway to the sec -- to the alternate escapeway?

MR. CONAWAY: I'm just saying, right now, initially, Eric, that every airlock in a mine is not on a separate split of air or ventilated.

MR. SHERER: Okay.

MR. MACLEOD: In your discussion on visitors and hazard training, and possibly some independent contractors who may not be in the mine for a length of time, you talked about an alternate training different than, probably, what other miners would get. You may not be able to do it now, but could you provide us with some information on what you envision this different training to be, or alternate?

MR. BUMBICO: Sure, we'd be happy to.

MR. MACLEOD: I appreciate it, thank you.

MR. KRAVITZ: I had one question. If you store SCSRs in an airlock, do you think they'd be substantially protected in an explosion -- in the event of an explosion?

MR. CONAWAY: Well, I mean, given any -- you know, multiple scenarios of what may take place, I mean, you have to pick a location and you have to place, you know, the SCSRs strategically in the mine. Are they going to be protected in all situations? I -- that -- I mean, that's very difficult to answer.

MR. FORD: Mr. Conaway, do all mines owned by Arch have a -- are those mines -- are all those mines on storage plans?

MR. BUMBICO: No, they're not.

MR. FORD: Okay.

MR. BUMBICO: All of them, with the exception of one of our subsidiaries, has a storage plan.

MR. FORD: Okay. The one that's not on the storage plan, or the ones that are not on the storage plans, do you keep the information that's -- concerning the SCSRs in those mines, such as the total number of SCSRs, manufactures, et cetera?

MR. BUMBICO: Yes, we do.

MR. FORD: You do? Okay. I guess that maybe could clarify, then, your statement that you think that this type of information should only be maintained in those mines which have storage plans, but yet, you seem like you do it in your other mines, also.

MR. BUMBICO: Well, also, with the introduction of the ETS, we will have a storage plan at one subsidiary that didn't have one previously, so it's information that we're going to have at all of our locations.

MR. FORD: Okay, thank you.

MR. SEXAUER: Any more questions? Gentlemen, thank you.

I think we'll take a 10 minute break right now.

(Whereupon, the proceedings in the foregoing matter went off the record for approximately 10 minutes.)

MR. SEXAUER: We'll go back on the record. Next speaker is Mr. John Gallick.

MR. GALLICK: My name is John Gallick, G-A-L-L-I-C-K. I am the Director of Safety for Foundation Coal Corporation.

Foundation Coal is the fifth largest coal company in the United States with operations in Pennsylvania, West Virginia, Illinois, and Wyoming. Foundation Coal has a strong interest in this emergency standard. I will be offering my opinion to the panel on specific issues within these regulations that either need clarified or that the intent of the regulation can be enhanced by changes in the present wording of the emergency regulation. I will address each segment of the regulation separately.

One, part 48, training. In general, I support the revised part 48 standard changes proposed in the emergency standard. I believe that there should be clarification as to what exactly will be required by an operator when training a non-miner. Using the definition of "miner" from part 48.2(a)(1), non-miners include visitors and people on the property for a short time frame. As presently written, the ETS changes only impact miners, yet the preamble discusses requiring hands-on training and SCSR transferring training for visitors. This issues needs clarified. Our position is that non-miners visiting the operations can receive adequate training via demonstration or video review of the use of an SCSR. Any visitor or non-miner is accompanied at all times by an escort. Visitors depend on these escorts to provide for their safety. Providing an overview of SCSR training without the detailed training needed for miners is adequate. To require hands-on training and transferring of the SCSR units for visitors will not enhance safety and will limit the number of visitors tours that mines will agree to accompany.

Number two, part 50, notification. The action reporting standard changes under part 50 are clearly intended to facilitate a rapid response by the Agency to serious accidents, particularly, those accidents that require additional resources for rescue and recovery. This is understandable and I support the attempt by MSHA to assure a rapid and coordinated response for those relatively rare instances. As written, however, the 15 minute notification requirement includes the entire list of accidents as defined in part 50 as being immediately reportable. I don't believe that was the original intent of establish a 15 minuet notification requirement. I believe that this standard would be enhanced by limiting the 15 minute response requirement to those events that require a rapid, coordinated response for rescue and recovery. That said, if the Agency chooses to require a 15 minute notification for all immediately reportable accidents, I believe that MSHA should provide one district phone number to contact, to contact MSHA, and not a call chain of numbers that has been typically used and is discussed in the preamble as MSHA's plan to receive calls. I believe that changing the MSHA protocol to providing a one-call number at each district will enhance the operator's ability to provide timely notification to MSHA. It is important to recognize that a number of other calls need to be made by that operator in the event of an emergency. By MSHA providing one number to call for notification, the operator can then turn his attention to his other calls and ensure that all the remaining calls required in an emergency can also be timely conducted.

I'd also like to comment on the practical effect of the requirement that all accidents listed as immediately reportable must be called into MSHA within 15 minutes. Prior to this change in the regulation, most incidents were not called in to MSHA by the surface attendant but were called in from someone in management who was notified of the event by that surface attendant. Generally, the person calling MSHA could answer questions and provide some detail as to the seriousness of the event. Granted, this was not in the 15 minute time frame, but the additional information and coordination was a benefit to both the operator and MSHA. In the preamble, the Agency has indicated that the 15 minute period begins after the operator has determined that an accident has occurred. Further, the Agency has indicated the operator needs to convey sufficient information so that the Agency knows what has happened. The difficulty is that the period of 15 minutes is far too short to gather any substantive information. The operator may only know that something that the Agency would consider an accident has occurred without having any details. Under the 15 minute notification requirement, it is more likely that the call to MSHA will be made by the surface attendant and only a bare minimum of details will be available during this call. This will just be a reality of the new system, however, it is not the best way to make certain MSHA learns of an accid -- emergency and has enough information to make subsequent decisions.

Number three, part 75, mandatory safety standards, section 75.3807(i). In general, I support the changes in the regulations that require the use of lifelines in escapeways. I think that this standard would be improved if an exemption was included that eliminated lifeline in track entries and in beltlines. The entries without track or belt structure may need lifelines as a guide for quicker escape. I believe that this guide is not needed where other structures such as track or belt structure is already available for guidance in escaping. Further, I believe that lifelines in/around track switches can actually be a detriment to the day-to-day mine safety. These lifelines fall loose from the roof. They can be caught by haulage equipment and either pulled down in a domino effect or possibly injure a person in or around the switch area. I ask the panel to consider these issues when developing the final regulation.

Lastly, in one of the question and answers provided for this section of the emergency standard, a question were asked about using insulated j-hooks to hang lifeline from mine's high voltage cables. MSHA's answer was that that was unacceptable. I respectfully disagree with that answer. The present regulation concerns only regularly-traveled under emergency-energized high-voltage cables. Hopefully, the need to travel under the high-voltage cable will never be needed, and any training sessions that can be conducted without traveling on -- can be conducted without traveling under unguarded high-voltage cables. It is difficult in non-track travelways to assure that the lifeline or other cables will not be hit by mobile equipment. Placing as many of these cables on one side of the entry minimizes this problem.

Section 75.1502(a)(1). I want to reinforce the process under section 75.1502(i)(4), sorry. We train our employees to fight fires as a first line of defense so we don't have a full-blown mine emergency. I commend MSHA for acknowledging this fact. I would ask that MSHA train their local inspectors and field supervisors to support and understand our plans for firefighting. There have been too many occurrences where fighting -- firefighting has been hindered by 103(k) orders or other orders of withdrawal from firefighting activities. Many of these orders of withdrawal are made over the phone. One of my issues concerning the immediate notification process previously discussed is that the mine-level caller may not either have the proper information because of the extremely limited time period for notification or may end up speaking to someone from the Agency who issues a blanket withdrawal order without really knowing what the operator is trying to do to control the emergency. We believe that MSHA can help in this training by directing local inspectors to become familiar with the mine's firefighting practices. It is my opinion that a 103(k) order withdrawal should be issued -- should not be issued until the Agency representative has enough details of the situation the operator is confronting and what actions the operator is taking to handle the situation. Operator evacuation and firefighting plans are designed to address the handling of emergencies. It is important to allow for these plans to proceed as designed. I believe that both the operators and Agency want the emergency plan of action that includes firefighting to be enacted and not to be prematurely halted due to miscommunication.

Section 75.1502(c)(1). I recognize that the standard interval for fire training -- fire drill training and, subsequently, mine emergency training, has always been "not more than 90 days." With the addition of more extensive training requirements in the ETS, I recommend that this time frame be modified to "once each quarter." This change will enable the operator to train more efficiently without any negative effect on the actual training standard. Large mines will be training over 400 people on SCSR transfers, escapeway systems, firefighting and evacuation drills. This can all be accomplished quarterly. By providing timing flexibility, crews can be pulled systematically for training. If there is a concern that someone might train at the end of one quarter and at the beginning of the next quarter, the rule could be written to provide that the training must be accomplished in a window of time. For example, the rule can require that training be accomplished in the months of -- in a month during each quarter, for example, January, April, July, and September. The schedule can be listed in the plan. We all want whatever training we do to be quality training. By simply changing the time frames so that we have flexibility in training during a month in each quarter, this quality can be enhanced. This it not much different than the present interpretation of an annual retraining date, where the due date for retraining is triggered not by the date of that training, but by the month of that training.

Section 75.1502(c)(2). I disagree with the requirement that all people must travel the entire escapeway every 90 days as part of the training requirement. This is, at best, rote training. Physically traveling an entry does not train a person on escape. It would be more logical to train miners on expectation training concerning their escapability in a mine emergency. Instructing workers on the entrances from their work locations to the escape system, the lifeline systems, SCSR locations, and physical issues in the escapeways, such as areas that are low or more difficult to travel, locations where decisions need to be made such as overcast banks, et cetera, would be better use of training time. It is more important to train miners on the decision making required in an emergency rather than engage in the drudgery of simply exiting through the escapeway.

We need to look no further than Sago to observe the necessity of this. The Sago miners tried to come out the track and the intake escapeway and were turned back in both cases. They then decided to barricade. It's far more useful for miners to use these types of situations as discussion points in training exercises and to understand these type of choices rather than trudging out of the entire escapeway every 90 days. Additionally, much of the NIOSH studies on escape emergencies discussed the fact that many times, the workers who are escaping have little knowledge of the location, size of a fire. Again, this is a training issue that can be of more beneficial use than -- working on this, than spending time walking the entire escapeway.

The second issue with travel of escapeways by all employees is the physical condition of people. There are a number of employees at mines that will have a difficult time walking the distances of some of the escapeways or the condition of escapeways, such as the travel height. This does not mean that in an emergency, that these workers can't escape. That's an entirely different issue. The question is, should an employee with an arthritic knee be forced to suffer for days after an escapeway walk, or is it more important that he know the escape system? I recommend that this section be changed to require the operator to provide quarterly training of all employees on escape routes, emergency escape scenarios, SCSR locations, and areas and escape systems where decisions for which direction to escape may need to be made. It is clear that 75.1500 will now be a major addition to the industry's training requirements. Let's use this time wisely to make miners better prepared for emergencies, rather than just traveling entries.

Section 75.1502(c)(2)(ii). I want to reinforce the position that donning and transfer training on SCSRs can be accomplished more effectively on the surface. I realize MSHA has stated in the Q&A on the ETS that this is acceptable, but I just want it restated. I do not object to transfer and donning hands-on training requirements. I recommend that this be modified, however, so that operations that have multi-types of SCSRs be permitted to train for varied transfer each quarter. For example, an operation may wear a beltworn unit such as an SR100 and have in storage other SR100s as the additional rescuer. This operation may also store in caches Ocenco units. In theory, the worker would transfer SR-100 to SR-100, SR-100 to Ocenco, or SR-100 to Ocenco and then back to SR-100. I recommend that one type of transfer be required to be trained each quarter.

75.1714-2 and 75.1714-4, signs. This may seem a small matter to the panel, but the ETS language requiring specific wording such as "self-rescuer" or "self-rescuers" is much too prescriptive. Whatever sign verbiage that is chosen by the operation to designate self-rescuer storage should be acceptable.

SCSR storages in escapeways. Section 75.1714-4(c) requires additional self-rescuers in the primary and alternate escapeways to augment other SCSR requirements when length of the escapeway is greater than one hour of travel time. A number of operations have escapeways in adjacent entries. Logically, one cache of rescuers properly located in the cross-cut between these entries should suffice for both escapeways. The Agency has rejected this idea. I believe the Agency is wrong. A self-rescuer cache in the cross-cut, properly marked, equipped with escapeway-sized doors as prescribed in the regulations, forming an airlock, does not hinder access to the rescuers or hinder escapability of workers.

Thank you for the opportunity to speak at this proceeding, and I will answer any questions you may have.

MR. SEXAUER: Do you have a question?

MR. SNASHALL: The 5010 notification provision has always required that the notification be immediate. To be clear, are you saying that non-rapid response events do not need to be immediately reported?

MR. GALLICK: I guess what I'm really saying is that in non-rapid response emergencies, is it better to have a delay in reporting with details of the event, such as a roof fall with nobody injured or an elevator with nobody on it that is not running, than to make a immediate call with no information and the turmoil that causes? In the past, frankly, we -- in those kind of events, we always went over the 15 minutes and, you know, but we always -- when we did call, there was detailed information available, you know, and the person calling was somebody who was familiar with the area or somebody from management. All I'm saying is, if you -- if we -- if you leave all the accident notification -- 15 minutes, please be aware that all we're going to -- all you're going to get is a very, very basic report. There was a roof fall reported by a fire boss in a return in 3 Left. No details as to -- will be available to that fellow that he's going to make in 15 minutes, I guarantee it, but he'll know it's a roof fall above the anchorage point, therefore, he only has the 15 minutes to call. Just accept that.

The other -- you know, my other point is, obviously, just, you need one phone number. We don?t need a call chain.

MR. SEXAUER: Okay. Thank you, Mr. Gallick.

MR. GALLICK: You're welcome.

MR. SEXAUER: Next, we have two speakers together, Chris Bryan and Mark Ellis.

MR. ELLIS: Good morning.

MR. SEXAUER: Good morning.

MR. ELLIS: I am Mark Ellis, E-L-L-i-S, President of the Industrial Minerals Association North America, or IMA-NA. With me today is Mr. Chris Bryan, B-R-Y-A-N, Occupational and Safety Health Manager for U.S. Silica Company, a member company of IMA-NA.

We plan to testify as a two-person and would prefer to respond to questions at the conclusion of our testimony. Is that acceptable to you, Mr. Chairman?

MR. SEXAUER: Yes, it is.

MR. ELLIS: The Industrial Minerals Association North America is a trade association representing producers and processors of industrial minerals, as well as equipment manufacturers, railroad and trucking companies, media companies, law firms, and consulting professionals that serve the industrial minerals industry. IMA-NA's membership currently include companies that mine and/or process all clay, bentonite, borates, feldspar, industrial sand, mica, soda ash, sodium silicate, talc, wollastonite, and other minerals. These minerals are the industrial feed stocks for the manufacturing and agricultural industries, providing the raw materials for such essential products as glass, ceramics, paints, plastics, metal castings, and fertilizer. All IMA-NA producer members operating in the United States are impacted by the Mine Safety and Health Administration's Emergency Temporary Standard on emergency mine evacuation, issued on March 9, 2006, specifically, the provisions of 30 CFR section 50.10 addressing immediate notification of MSHA by mine operators when an accident occurs. IMA-NA is pleased to testify on the proposed rule on their behalf.

Requiring that MSHA be notified within 15 minutes of an accident in all cases is impractical and even may be dangerous. In the event of a mine emergency, mine personnel immediately are engaged in activities designed to save lives and limit harmful effects. Reasonable and timely notification to MSHA is necessary but not such as it has -- not such that it has the potential to distract mine personnel from lifesaving activities. Whether such a stringent requirement would endanger or assist an injured miner will depend upon the situation.

The former requirement of 30 CFR section 50.10 that "if an accident occurs, an operator shall immediately contact MSHA" could accommodate such situations. As MSHA notes in the preamble to it's proposal, the Mine Safety and Health Review Commission has observed that "immediately" is a term of common usage and that the application of the former requirement must be evaluated on a case-by-case basis. We concur. It is not reasonable to require notification to MSHA within 15 minutes of all accidents occurring, since it could distract mine personnel from actions needed to save lives.

MSHA, itself, recognizes that a "bright line" 15 minute immediate notification rule is not appropriate in all circumstances. The current CFR 50.10 provides that "if communications are lost because of an emergency or other unexpected event, the operator shall notify MSHA at once without delay and within 15 minutes of having access to a telephone or other means of communication." Should not a similar exception exist for mine personnel engaged in actions to save lives? We think so and believe that the straightforward requirements for immediate notification contained in the former 30 CFR 50.10 is best suited to address such exceptions. A performance-based standard is preferable to a specification-based standard.

I'd now like to turn the microphone over to Mr. Bryan.

MR. BRYAN: Thank you, Mark, and good morning. I'm Chris Bryan, B-R-Y-A-N, Certified Mine Safety Professional, and I'm the Occupational Health and Safety Manager for U.S. Silica Company, a member company of IMA-NA.

U.S. Silica Company represents more than a century of mining and providing processing experience in industrial minerals. It has established a standard of excellence in the production of silica and industrial -- other industrial mineral products. That commitment to excellence extends to providing a safe and healthful workplace for it's employees.

IMA-NA does not disagree in concept with the rationale advanced by MSHA in it's support of proposed rule requiring mine operators to immediately notify MSHA of an accident. Specifically, coordination of appropriate mine rescue and other emergency response, enabling help to arrive sooner at the mine can protect miners from grave dangers of physical injury and death and activation of MSHA's district emergency response plan.

Operator notification to MSHA in the event of a mine accident is vital to enable the Agency to respond effectively in emergency or potentially life-threatening situations; however, what happens when mine personnel, perhaps, as few as one or two miners, are confronted with an injured miner and as first responders, they are called upon to administer first aid? Should they cease administering cardiopulmonary resuscitation or applying direct pressure to a bleeding wound, or treating an individual in shock? We think not. Again, reasonable and timely notification to MSHA is necessary, but not such that it has a potential to distract mine personnel from life-saving activities. It is not reasonable to require notification to MSHA within 15 minutes of all accidents occurring because, in some instances, it could distract mine personnel from actions needed to save lives.

Could other situations exist where it would not be reasonable or appropriate to notify MSHA within 15 minutes of an accident? Conceivably. We would all hope -- we would hope that all mine operators would recognize that notification of MSHA of an accident is urgent and must be made a priority; however, we would hope that MSHA would recognize that there are situations that can occur where strict adherence to the 15 minute rule, the 15 minute reporting requirement, could endanger the life of one or more miners.

The straightforward requirement of the former 30 CFR 5010 for immediate notification is best suited to address such situations. As a performance-based standard, it is preferable to the proposed 15 minute specification-based standard.

Thank you, Mr. Chairman, and members of the panel, for your attention. Mr. Ellis and I are now available to respond to your questions.

MR. SEXAUER: At this point, we have no questions. Thank you very much.

Our next speaker will be Jack Henry and another gentleman will be joining him, I think. If you'll use the microphone in the center.

MR. CONRAD: Good morning.

MR. SEXAUER: Good morning.

MR. CONRAD: Thank the panel -- we thank the panel for your travels and your participation, here, in Charleston, today.

The -- we represent Mine Safe House. It's a limited liability company in West Virginia with affiliation of other international concerns in the research industry and in the carbon industry.

MR. SEXAUER: Could I ask you to say your names for the record, please? I had a little difficulty reading it on the list.

PARTICIPANT: We can't hear.

MR. CONRAD: My name is Erwin Conrad and with me is Jack Henry. We represent Mine Safe House LLC.

We commend the panel for being here and we also recognize the critical importance of escape. We believe, as miners underground believe, that escape is the first thing that enters their mind in an emergency. An escape must be emphasized. But, we are equally reminded by the haunting words and the letter of Randy McLoy that sometimes, escape is not possible. And, his words saying that they tried to travel out and they were blocked, to me, that says that they tried to escape, and we've heard other speakers say that they tried in a couple of different ways to escape and were unable to escape.

Our concern that we would like to address is that the critical SCSRs that are necessary for escape are not being protected adequately. If you have SCSRs that will be degraded or compromised or exploded in an explosion or a fire, then they should be protected adequately. If they are to be stored in a plastic container, a wooden box, then certainly, in a mine fire that can reach intensity of 1,900 degrees Fahrenheit or an explosion of 50 to 75 PSI, they're not going to be protected to be available for the miner in the event that they need it.

We are concerned about that and if there's affordable and safe technology to protect the SCSRs, we would encourage the panel to adopt standards to allow those to be used. In that connection, as well, when miners are unable to escape, there has been mentioned of safe havens. It's been called shelters, refuge chambers. We call it a safe house. We are concerned that with the experiences of MSHA as noted in the Federal Register of the March 9, 2006, hearings concerning the reported underground fires, 56, I believe, in a 10 year period of 30 degrees or greater duration and the studies by MSHA of the various disasters in the last 50 years, indicating that mine fires will sometimes range to 1,952 degrees Fahrenheit, that explosions have had measured intensity up to 75 PSI, we are concerned with some of the comments indicating that an acceptable level for resistance to fire would be 300 degrees Fahrenheit and an acceptable level to explosion would be 26 PSI for any sort of shelter, chamber, or safe house.

We are particularly concerned in that there are materials and prototypes have been built by our company with the wonderful assistance of the Coal Research -- National Coal Research Facility at West Virginia University and two international firms that will resist fires beyond 2,000 degrees Fahrenheit and explosive forces to 75 PSI. Also, the material does not have the thermal conductivity of steel, which degrades at 850 degrees, and will conduct heat to the inside 460 times greater than Grafoam Safety Foam, which is used in the prototypes that have been developed to respond to Sago and to respond to Alma and other such catastrophes in the past.

Our concern is that underground, the most important asset is not the continuous miner or any other piece of equipment, it is the coal miner or materials miner, and if we can't provide for their safety, truly, in a safe structure, then all of the other components and all of the other assets that would be utilized to try to help them could be nearly worthless. If there is safe and affordable technology, then we would encourage you to set standards that would allow that safe and affordable technology to be used. It does exist, it has been privately tested, it will be submitted to MSHA for testing, and we -- it's our position to encourage you to not either encourage states or, through MSHA, the entire industry to adopt standards that are less than safe for miners underground.

We are particularly encouraged by Illinois and other states that have either passed or are considering passage of provisions requiring shelters underground. Again, we understand that every coal miner wants to escape, but if they can not and if they are to be provided something that's pinpointed so that they can be found in a reasonable period of time, we believe that they're entitled to have breathable air for a sufficient period of time at a minimum 72 hours, not, as some have been reporting, 24 hours, and that they be in a structure that will resist all measured underground fires and explosions that have been experienced in the past.

That is something that we would encourage you to look at. We will provide you the test results on the material that is in prototypes that were available for inspection at Wheeling at the wonderful symposium that was sponsored there. Some of you may have had an opportunity to see one of the two prototypes that were taken to that particular location.

With that, I'll ask Mr. Henry if he would like to make some remarks.

MR. HENRY: Just briefly, again. I'm Jack Henry, I'm a pastor. Right quick, you're wondering what in the world is a pastor doing here? Well, I was once a coal operator and, but, for the last 25 years, I've been in ministry.

But, I've been real concerned that we have all this great natural resource wealth but we weren't getting the maximum dollar value that we could be getting by bringing them to their ultimate product that they could become and to make a long story short, I began to study and that's where I first met the chemical engineers and the industrial engineers, the civil engineers at WVU, and gave them my concerns, and I learned that they had been working for many years to try to bring these natural resources to this maximum dollar that they could become. I learned that they, too, were as interested as I was in creating jobs in West Virginia, and so, with that in mind, the chain led to a major company, Graftech, by name, who is already making some things that had been jointly discovered by WVU, and Graftech, through their research, but long story short, I saw these materials that they had made. I was able to be there when they tested them, I experienced the fire resistance that they used with the torches and other -- and then, they showed me the testing that they had done.

It was collision-resistant material, it was explosion-resistant, it was fire-resistant, and the thought that came to our mind was that we ought to be making this into armor protection for military applications, and we began to pursue that, and we were making great headway, but in January, another organization, by the way, that we formed, was called Believe in West Virginia Leadership Foundation, and in that organization, that's how I met Erwin and he became a part of that a couple of years ago with us.

But, we began to move toward this armor protection, but in January, when the Sago thing happened, one Mr. Conrad's clients had asked him -- had given him his idea about a safe house and Erwin right quick called me and the rest -- we began to work and went back to revisit WVU and these Graftech and others and all of us were on the same page, that we believe that this was kind-of divinely led, that we could make a safe house, and so, for three months, we crammed, we worked, and we traveled, and we brought to pass, and we brought into existence this prototype that we're talking about and we believe that it's portable enough to be moved inside the coal mines, it can be brought up within 200 feet of the men at all times, in a section, a normal section. It can be adapted to long wall, of course, the structure would be different. It could be adapted to low-vein mining, low coal, and -- as well as the high coal seams.

We really believe that had this technology been in existence and been in operation at Sago, that those 12 miners might have walked out, had they had this safety for the 72 hours that we're talking about having.

So, we're motivated not by any greed but -- by creating jobs, yes, but safety of these men was the highest priority that we have, and so, gentlemen, the things that Mr. Conrad told you are in existence and we would welcome the opportunity to demonstrate them, and we'll -- that's about what I have to say for you.

MR. SEXAUER: Gentlemen, thank you very much.

Let me just reiterate what I said earlier, at the outset, that the Agency's position is that our first response should be to evacuate the mine and that barricading would be the last line of defense for the miners.

The next speaker on the list is Elizabeth Chamberlin from CONSOL.

MS. CHAMBERLIN: Ladies and gentlemen --

MR. SEXAUER: Excuse me. Could we ask you to speak into the larger microphone?

MS. CHAMBERLIN: Okay. Ladies and gentlemen, good morning. My name is Elizabeth Chamberlin. I am General Manager of Safety for CONSOL. I have with me today Todd Moor, who is a Chief Inspector for the Safety Department with CONSOL Energy. He is also a member of the West Virginia Mine Safety Technology Taskforce.

CONSOL Energy is a multi-energy producer of coal, gas, and electricity. We currently have 17 mining complexes located in various states within the United States.

MR. SEXAUER: Excuse me, Elizabeth.

MS. CHAMBERLIN: Yes?

MR. SEXAUER: Would you mind moving the microphone a little closer to you, there? Thank you.

MS. CHAMBERLIN: And, actually, I can speak up, gentlemen. I've had a long career of having to speak up and make a point, but just keep reminding me.

All of the CONSOL Energy mining complexes are associated with underground mining operations, with the exception of some mining that's occurring at Mahoning Valley in Eastern Ohio, Mill Creek in -- operations in Eastern Kentucky employs a combination of underground and surface mining methods. Currently, we are operating in Utah, Kentucky, Virginia, West Virginia, and Pennsylvania.

CONSOL Energy appreciates the opportunity to comment on the Emergency Temporary Standard on emergency mine evacuation and we hope to offer a few thoughts and recommendations on improvement of the Emergency Temporary Standard.

We recognize that the ETS was prompted by the high level of concern for miner safety coming out of the tragic events in the West Virginia mining industry earlier this year and I want to assure the Agency that we support the underlying goals of the ETS fully.

Some of our comments, I will try not to duplicate comments made by some of the other operators, but we do have common thoughts on many of these processes.

CONSOL Energy supports the revised training requirements for miners contained within part 48, but we would like to use the opportunity to comment on two specific areas.

First, with regard to hazard training, we recommend clearly providing the operators the flexibility to accept form 5023 documentation of applicable, up-to-date SCSR training in lieu of hands-on training for non-mine employees such as visitors, vendors, contractors, and other non-mining personnel. We support hands-on training for these personnel, we simply do not see the need for redundant training if they have had recent training within the proper time frames.

The second recommendation deals with 30 CFR parts 48.5(b)(5) and 48.6(b)(5), requirements for emergency evacuation and barricading instructions for new and experienced miners. CONSOL Energy sincerely believes that this industry must focus it's emergency response efforts first on prevention, second on fire fighting preparedness, and third on evacuation training, in that order. Given the fact that coal is a fuel source and given the historic evidence of secondary explosions, our employees must be taught, and in CONSOL Energy, are taught that barricading is the avenue of last resort. We appreciate the Agency's position on this point.

CONSOL Energy has put these recommendations into practice and has benefitted from strong management and employee support at all levels as a result. Our efforts are extensive and will be touched upon in greater detail later in our comments.

Next, let me turn to the 15 minute notification requirement of part 50. The ETS explains that the purpose of revising part 50 to include a 15 minute notification requirement is to enable the coordination of appropriate mine rescue or other emergency response. This objective is commendable, however, the part 50 definition of accident appears inappropriately broad for this purpose and may prove counterproductive.

As detailed in the NMA comments of April 28, experience has shown us that it is not necessary to activate mine rescue personnel or local emergency response resources in many of the instances that are defined within part 50 as accidents, and as earlier speakers have mentioned, there would be areas such as unplanned roof falls at or above the anchorage point or damage to hoisting equipment that interferes with it's use for more than 30 minutes.

By requiring the toll-free answering service maintained by MSHA Headquarters, which relies on individuals with no hands-on mining experience, to distinguish whether a call is a true emergency, we believe, sets the stage for false alarms along with the unnecessary mobilization of emergency response personnel. We are also concerned that the resulting media reporting frenzy that follows such situations will further exacerbate such an error and will also create angst among our families and negative press for the industry as a whole.

Therefore, we believe a preferable alternative would be to limit the 15 minute notification that is made to just the emergency call center, to be limited just to accidents that pose a threat to life or ones that require rescue or other emergency response for trapped or injured miners.

Next, I'd like to turn to the mandatory safety standards under part 75, first with regard to section 75.387(i). CONSOL Energy supports the Agency's efforts to facilitate evacuation under adverse conditions. We commend the Agency for drafting section 75.380(d)(7) to permit a lifeline or an equivalent device. Such an important issue isn't -- is -- with such an important issue, it is important to elevate form over substance. Recognizing that lifelines in many track entries and belt entries may be ineffective and potentially hazardous, we encourage the Agency to maintain an open mind with regard to any proposals for equivalent devices. Where lifelines are being used within CONSOL Energy, we are utilizing the Cav (phonetic spelling) lifelines with reflective materials along with cones pointing inby per the NIOSH-recommended convention.

Our mines are also storing taglines in our SCSR storage boxes. These taglines are set up in much the same way as the taglines that are used for our mine rescue teams.

With regard to section 75.1502(a)(1), CONSOL supports the NMA's comments on this section. The section addresses the procedures for rapid assembly and transportation of necessary miners, fire suppression equipment, and mine rescue apparatus to the scene of the mine emergency. To prevent full-blown mine emergencies, however, and recognizing that the first few minutes of a fire are critical, CONSOL Energy elects to prepare our employees and expects them to be first responders, and we do this by providing hands-on firefighting training using the resources that are available to our miners at their worksite. Experience has shown us that this training has given our employees the confidence to efficiently and safely fight a fire when required. This training is only a portion of our total program of prevention, fire fighting preparedness, and evacuation training.

A few examples may be helpful in understanding our commitment and investment in this philosophy. CONSOL Energy's mining group employs five Fire Prevention Managers who audit and maintain our fire prevention and emergency response preparedness efforts. Three mobile gas chromatographs and skilled technical personnel are another part of this arsenal.

At the next level, CONSOL is extremely proud to have developed one large, cohesive, well-equipped mine rescue team approximately 120 employees strong, consisting of members from our 12 major underground mining operations. These team members are equipped and trained far in excess of any regulatory requirements and participate in mine rescue competitions to further enhance their skills. Our team, along with many other fine teams, assisted at Sago and Aracoma Alma and we would like to take a minute to commend all of the teams for the dedication and skill that was shown under those difficult circumstances.

To assist teams, we have also strategically located at two separate spots storages of or caches of supplies that are necessary, based on our experience, for mine rescue efforts. We think by doing this that we can expedite our response to any emergency situation that we may encounter within our operations.

Internally-conducted MERD exercises also forms a part of our program and I will take a moment to thank MSHA and the state mining agencies for their participation in these exercises with special thanks to Virginia DMME, it's Chief, Frank Linkous, and it's staff, particularly, Wayne Davis.

We commend the Agency, also, for the focus on smoke training. For some years now, CONSOL Energy has provided training in smoke for our mine rescue teams and in-smoke evacuation training at our mine sites for all of our employees.

We have utilized the services of NIOSH and the West Virginia Extension Service, but we now also own 16 smokers of our own to facilitate training whenever it is needed.

Finally, I will touch briefly on CONSOL Energy's two communication centers, one of which is dedicated strictly to our coal mining operations. These communication centers are key components in CONSOL Energy's emergency response process. they are manned 24/7 by knowledgeable personnel. They act as comprehensive communications and monitoring hubs for key installations and systems such as fans and CO monitoring systems. In addition to day-to-day handle -- handling day-to-day communications throughout the company, these centers are also tasked with activating mine rescue teams if needed and making emergency notifications when specifically requested.

In summation, emergency response preparedness, in our mind, is more than SCSR and evacuation training. While improving our evacuation capabilities and encouraging the Agency in their efforts in this regard, the industry must also maintain it's primary focus on prevention and fire fighting response.

Now, I'd like to turn next to section -- to comments on section 75.1502(c)(1). CONSOL Energy, here again, adopts the NMA recommendation that the 90-day time frame for training under 75.1502(c)(1) be modified to once each quarter. This change would enable the operator to train more effectively without any negative effect on the actual training standard. This is particularly important to CONSOL Energy. Our large mines will be training 400 to 600 people on SCSR transfers, escapeway systems, fire fighting, and evacuation drills, making flexibility in the timing of this training an important consideration.

To alleviate any concern of a person being trained at the end of one quarter and at the beginning of the next, however, we would suggest that MSHA could require that the training be accomplished during a window of time. For example, the rule could require that training be accomplished in a month in each quarter, for example, January, April, July, and September. This schedule would -- could be listed in the mine plans that are submitted to the Agency for approval.

Proposed revisions to 75.1502(c)(2) will be my next area of comment. CONSOL Energy has serious reservations regarding the training requirement mandating all miners travel an entire escapeway every 90 days, and we have concerns our employees will come to view these drills as punishment rather than training when walking rather than riding out of the escapeway is mandated. A more effective method of training miners on escapeways as commented upon by previous speakers would be the exception training, instructing miners on entrances from their workstations, the location of lifelines and SCSR caches, any significant unusual physical characteristics of the escapeway, and the -- showing the locations where important escape decisions would have to be made.

As an example, let's look at a typical CONSOL Energy long-wall section. Escapeways are at an entry that is generally isolated with a solid pillar at once side and a stopping line on the other side. Once you are in the escapeway, there is no escape decision to be made until you reached the neck of the section or perhaps even the escape shaft. Under this circumstances, showing employees the entrance to the escapeway, transporting them by vehicle to the location of the SCSR storage and to decision making junctions would achieve enhanced training and education while still allowing for training on the condition of escapeways and locations of lifelines, and stored SCSRs, where applicable.

Using this proposal, quality focus training is achieved, which we feel that this result is less likely under the proposed Emergency Temporary Standards.

Referring to section 75.1502(c)(2)(2), CONSOL Energy, again, adopts my reference, the NMA comments on SCSR training requirements relating to this section. CONSOL joins other NMA members in supporting the hands-on training requirement with transferring and donning of SCSRs, however, at sites with multiple -- where multiple units are used, experience indicates that enhanced training would be achieved if we could focus on one specific element during each quarter of training.

In addition, this training should be done in the proper training environment, and we would suggest that reality training be done only periodically, as determined by the operator. For example, in CONSOL Energy mines, our employees will wear Ocenco M-20 units with Ocenco EBA 6.5 devices stored on personnel carriers, in section storage areas, at construction sites, along our belt lines, and at various other key locations, to provide appropriate coverage for our employees. CSE SR-100 units will -- may be available for specialized uses.

Under the NMA proposed modification to this provision, the first quarter training might well focus on the transfer from an Ocenco M-20 device to an Ocenco EBA 6.5 device. The second quarter training may focus on the donning of an SR-100 unit, or the donning of an M-20 unit, or the donning of an EBA 6.5 unit.

More comprehensive training may also be considered for part 48 annual refresher training under the type of scenario that we are proposing to you.

These proposed modifications, in our view, place quality over quantity and places the best interest in the safety of our employees at the forefront.

Turning next to the revisions to section 75.1714-2 and .1714-4, CONSOL Energy supports the Agency's efforts to enhance the resources available to our employees and others for the safe evacuation from underground coal mines in the event of an emergency. The industry is committed, and CONSOL is committed, to preventing a repetition of the tragic loss of life suffered at Sago and Aracoma Alma. In an emergency situation, however, it is critical that the additional storage of SCSRs contemplated by the Emergency Temporary Standard be used for prompt evacuation from the mine. Again, as we've said before, barricading remains a last resort.

ETS section 75.17-4(b) provides that if a mantrip or mobile equipment is used to enter or exit the mine, additional one-hour or greater SCSR devices shall be available for all persons who use such transportation. In contradiction with the plain language of this provision, we have found that various MSHA districts are interpreting this section, and, we believe, misinterpreting this section to require the storage of two SCSRs per employee on the personnel carrier if a one-hour belt-wearable unit is not employed. Other methods are available, as illustrated by CONSOL Energy's submitted plans which fully comply with the requirements of 17.14-4(b) and with the purposes of that section.

For this reason, CONSOL takes exception to the more prescriptive district positions. Our operations have had a generous Ocenco SCSR storage plan for many years. Under our current plans, our in-mine storage deploys 14 times more units underground than is required by the ETS. These units, as I mentioned before, are stored strategically throughout the mine. In addition, under our submitted ETS storage plans, our employees will be provided with belt-wearable Ocenco M-20s that will replace the W-65 chemical units that are currently in use. This means our employees will always have multiple oxygen units readily available for their use should the need arise.

Turning to SCSRs in primary and alternate escapeways, that's section 75.1714-4(c), which requires additional SCSR storage in the primary and alternate escapeways to augment other SCSR requirements, where the requirements do not provide enough oxygen for all persons to safely evacuate. Where the operator determines additional SCSRs are required, the operator must submit a plan setting forth the location, quantity, and type of additional SCSRs, and they may be required by this section, by the district -- under this section, by the District Manager, to demonstrate the plan's adequacy. Under the plain language of this provision and the preamble, a number of operators, including CONSOL, have proposed, as an alternative, to use airlocks located between the adjacent escapeways for storage of SCSRs along with other important emergency supplies. The use of an airlock has the additional benefit of providing employees with a space that is somewhat isolated from the main airflow courses for the transfer of SCSR units. Another alternative proposal would be to build an SCSR storage unit into the stopping to permit storage units to be accessed from either escapeway.

CONSOL believes both of these proposals are simple, functional, and mine worthy, however, in it's recent guidance documents, the Agency has rejected these proposals, taking a prescriptive position that equal numbers of stored SCSRs required in both escapeways. I believe that the stated basis for this rejection is speculative and that it encroaches on the -- and that it should be withdrawn. 17.14-4(c) does not require that identical quantities of additional units be stored in both the primary and alternate escapeway. Instead, this section requires additional units in both escapeways. Furthermore, the operator's alternatives, as described above, would place the SCSRs in locations that would satisfy both primary and secondary escapeway storage.

We recommend that the Agency consider a specification standard such as one that has been adopted by various other states which establishes SCSR storage locations at simply based intervals, established on entry height and seam characteristics. However, a standard along these lines, while easily understood and implemented, we believe, should also recognize the quantity available -- of available oxygen provided by the SCSR unit utilized at the mine and not be limited simply to the rated capacity of the SCSR unit.

Finally, the preamble to the Emergency Temporary Standard poses a series of questions. Most have been, I believe, addressed by CONSOL Energy's testimony. A few have not, and we will submit supplemental comments, written comments, to the Agency. We want to touch upon two of the inquiries, however, directly.

The first one is the question of whether the operator should report details such as serial numbers for SCSRs to the District Manager. CONSOL shares Arch's view on this position. The point we would like to make that is, is with the increasingly large number of SCSRs that are being placed underground in all of our mining operations, there needs to be a good reason for this type of data gathering on any increased frequency. More importantly, the Agency needs to encourage the manufacturers of these devices to incorporate a tracking device, whether it be some type of antenna or barcode into the devices, simplifying the collection of this data. The technology is available, the encouragement would be appreciated, and it is the direction that CONSOL Energy is attempting to go with the storage of our units.

The second question we'll address is the question as to whether or not operators should be required to notify the Agency of SCSR failure or use as well as requiring the operator to maintain failed units for 90 days. We have no objection to notifying the Agency of failed units or providing them with these units subject to the Agency's agreement to allow the operator to participate in any testing of the failed units and subject to the Agency's agreement to share any test results with the operator; however, we see no valid purpose for the Agency to be notified of used or damaged units unless we see a pattern of damage that was -- that is indicative of a product defect. In other words, we see no use -- we see no good purpose of notifying a unit if an SCSR is run over by a scoop and destroyed. That's just one example.

In closing, let me thank you, again, for providing us with the opportunity to comment on this standard. I would be pleased to respond to any questions you may have.

MR. SEXAUER: Ron, you have a question?

MR. FORD: Yeah. You said that in some CONSOL mines, you have more SCSRs than that are required by the ETS rules? Was that correct?

MS. CHAMBERLIN: Yes.

MR. FORD: Okay, how many --

MS. CHAMBERLIN: And, we are in the process of augmenting our supplies of SCSRs underground currently, and of course, we have differing requirements in the state of West Virginia than we do in our other operations, regulatory requirements, as you are well aware.

MR. FORD: Okay. Do you know what percentage that is where you have more SCSRs in mines than are currently required than the ETS rule? Is it 90 percent of your underground coal mines, or --

MS. CHAMBERLIN: Oh, they would be all of our underground coal mines.

MR. FORD: All of them?

MS. CHAMBERLIN: Just because of the existing caches that we have and we have already augmented those caches once with our available units and we have orders in which will, again, significantly augment those units. As I said, our calculations are that it's -- at our mines, it averages 14 times more than what is required by the ETS.

MR. FORD: Okay, thank you.

MR. KRAVITZ: Elizabeth, as far as the evacuation and smoke training, is that being carried out underground or is that in a surface facility?

MS. CHAMBERLIN: Both.

MR. KRAVITZ: Okay.

MS. CHAMBERLIN: Mine rescue team training is conducted at Lake

Lynn. Underground training is -- for our employees, for evacuation, is conducted underground at the individual coal mines. We also use the smoke trailer or chamber that the West Virginia Extension Service has available to us. So, we use whatever means happens to be available at the time we want to do the training. The important aspect of it is the exposure to smoke and the training that goes along with that to show our employees how to deal with the smoke.

MR. KRAVITZ: Okay. Can you estimate what percentage of your escapeways, both alternate and primary, are travelable by mechanized vehicles?

MS. CHAMBERLIN: Any escapeway that we have that's in our track entry.

MR. KRAVITZ: Uh-huh.

MS. CHAMBERLIN: And, a percentage, about 50 percent.

MR. KRAVITZ: About 50 percent? Okay. And, you said you're now in the process of trying to incorporate tracking devices in your SCSRs. What method are you using for this?

MS. CHAMBERLIN: We've been talking with the -- with Ocenco, with the manufacturer. They're here today. They might be in better position to comment than I am, but apparently, it's a -- rather than being a barcode, which is what we're using in other applications within CONSOL, apparently, it's some small transmitter device. But, same concept.

MR. KRAVITZ: Okay, same --

MS. CHAMBERLIN: Same concept. You know, yourself, that if one of the more deadly attacks that any safety person, or, at least in our operation, any safety person had is to have their light shining on a Ocenco serial number and copy them down at the same time. We're trying to facilitate that and make better use of our time.

MR. KRAVITZ: Okay. I think it would be nice to have that included as part of the record. If you could, in your formal comments, by the end of the comment period, if you could detail that, I'd appreciate that.

MS. CHAMBERLIN: We would do that.

MR. KRAVITZ: Okay.

MS. CHAMBERLIN: Again, it's in the talking stages as we go, and quite frankly, we have two priorities here. One is getting something in the new units that we're purchasing. Secondarily, it's trying to incorporate something in our existing caches of SCSRs.

MR. KRAVITZ: Sure, okay.

MR. SNASHALL: You mentioned, when you were talking about smoking in training -- or, smoke in training, something about 16 smokers.

MS. CHAMBERLIN: Yes.

MR. SNASHALL: Did I get that correct?

MS. CHAMBERLIN: Yes, they're --

MR. SNASHALL: Could you describe what --

MS. CHAMBERLIN: Smokers are a device that's utilized to generate the white smoke that's used underground for smoke training. It's just the equipment.

MR. SNASHALL: You're talking about theatrical-type equipment?

MS. CHAMBERLIN: Yes.

MR. SNASHALL: And, is that theatrical-type equipment readily available to the industry?

MS. CHAMBERLIN: We were able to obtain it. Whether it was readily available or not, I don't know. We made a decision to obtain it and placed a purchase order.

MR. SNASHALL: Do you know approximately how much a unit costs?

MS. CHAMBERLIN: You know, I did, but sitting here today, I don't. We can submit comments on that. No, I -- we -- it's -- we can give you that information. That's not a problem.

MR. SEXAUER: Okay, we have no more questions.

MS. CHAMBERLIN: Thank you.

MR. SEXAUER: I think what we'll do at this juncture is to take a break for lunch and reconvene at 1:00. We have about four or five more speakers listed. If anyone else would like to speak, feel free to sign up on the speaker list and -- so, we'll recess now until 1:00.

(Whereupon, the proceedings in the foregoing matter went off the record for approximately one hour.)

MR. SEXAUER: We're going to go back on the record. Good afternoon. Our first speaker this afternoon is Chris Hamilton with the West Virginia Coal Association.

MR. HAMILTON: Good afternoon. Did that pick up? I'm Chris Hamilton, West Virginia Coal Association.

I appreciate the opportunity to comment on the Emergency Temporary Standard before us today. The West Virginia Coal Association is a trade association comprised of coal-producing companies that account for approximately 75 percent of the state's coal production. West Virginia's coal industry also accounts for nearly 110 million tons of annual coal production from underground mining operations, thus, West Virginia remains the leading underground coal producing state in the country. Our membership also includes land companies, equipment manufacturers, mine supply and service companies.

Again, we appreciate the opportunity to participate in this rulemaking and to comment on MSHA's Emergency Temporary Standard for mine evacuation, published in the Federal Register on March 9, 2006. We remain committed to operating the safest mines in the country and the world and offer the following comments to enhance and strengthen the overall effect of this rulemaking.

Initially, we would also like to point to the comments --

MR. SEXAUER: We're having a little trouble with the mic. Let's go off the record and see if we can fix this.

(Whereupon, the proceedings in the foregoing matter went off the record for approximately two minutes.)

MR. SEXAUER: Okay, we'll go back on the record.

MR. HAMILTON: I thought maybe you had this space reserved for David McAteer the way this mic system's acting up, here.

We would also like to point to the comments presented by the National Mine Association at the public hearing held in Arlington, Virginia, on April 28, and would observe that many of our member companies and safety professionals within those organizations contributed to the development of those comments. For the record, we wholeheartedly embrace and support those comments and would urge your consideration of the same. Many of the highlights were presented here today by representatives of Arch Foundation and CONSOL, and again, we would support those remarks as well.

We also would like to point out that today's hearing comes nearly four months after the enactment of a major piece of legislation here in West Virginia, West Virginia Senate Bill 247 addressing many of the same topics in requirements that are presented within MSHA's ETS. It's also noteworthy to observe that a special joint labor-management workgroup comprised of Mine Health and Safety professionals was also convened to assist in the development of administrative rules to implement the specific requirements of Senate Bill 247. These rules were initially filed on January 1 and revised on February 28, earlier this year. The amended emergency rule filed on February 28 contains a number of changes to the February 1 version based on a careful analysis, evaluation by the Mine Safety and Technology Taskforce of Procedures, Protocols, and Requirements for mine operating procedures, mine emergency preparedness, mine evacuation needs, including the proper sequencing of escaping from a mine and the placement of additional breathing apparatuses and lifelines throughout the mine.

We respectfully submit for your consideration and request that MSHCA examine these requirements which I'll submit for your reference and to consider modifications to your ETS consistent with West Virginia's requirements, or alternatively, consider developing a procedure within this rulemaking for MSHA to approve a state plan for adequately addressing these topics in a similar fashion that MSHA approves state plans for important miner certification programs. Such plans would meet specific criteria and standards consistent with those in federal law and would additionally provide the same or a higher level of safety or protection for mines and miners. We recommend the same process be adopted for state-approved plans for mine evacuation programs and requirements.

Regardless of the approach MSHA elects to proceed, it is undeniable that MSHA's current ETS and West Virginia's emergency rules address the same -- many of the same topics, but do so quite remarkably in a different fashion. Unfortunately, this leaves coal operations in West Virginia with two distinct, separate compliance standards. To avoid compliance and enforcement complexities, the state and mine safety offices should join together in this important endeavor to provide uniformity within the rules. I would also observe that many, if not all, of the members of that state taskforce, including their chairman, are here today, or at least were here today before we broke, in the event someone wanted to initiate that dialogue.

We would also call to your attention to the West Virginia Mine Safety Technology Taskforce, which is a second joint government, management, and labor entity, and it's obligation to issue a final report by June 1 of this year, outlining it's specific findings and recommendations with respect to the implementation and compliance of similar mine safety requirements.

This taskforce was created to study issues related to the implementation, compliance, and enforcement of the safety requirements contained within the state's emergency rule dealing with additional SCSRs, escaping sequencing, escaping procedures, mine emergency operations, and preparedness, generally, as well as the placement of lifelines in escapeways.

As an industry, we are remained committed to operating the safest mines in the country, and for that matter, the world, and pledge our full support toward achieving this shared goal. Since January, we have drawn upon our collective mine health and safety, and technical and operational expertise to work with state and federal regulators, miners, and other concerned stakeholders to identify and implement mine health and safety measures that will affect real change and real improvement in the mining industry. Among those initiatives include increased numbers of SCSRs throughout practically every mine in West Virginia. There are now additional supplies with strategically placed SCSRs per miners in all mines. West Virginia mines have expanded the number of lifelines and fire protection systems that are available. Mine operators have stepped up their mine emergency training programs. All mine emergency and preparedness drills and procedures have been updated and reviewed. Operators are providing increased training and simulation drills currently to ensure that miners and supervisors are fully prepared in case of emergencies. Our association of members are working with the West Virginia Office of Homeland Security and Emergency Response along with state mine safety office officials to develop the very best in immediate accident notification system to ensure timely rescue in the event of an emergency.

Along those lines, I also want to point out that we've had several months of experience with our immediate notification standard. I believe the standard contained in your ETS mimics -- by and large, mimics the standard embodied in West Virginia's law and rule, and as was previously pointed out, here, earlier today, about 90 percent of all the calls that have come into MSHA during last year are of a nature that mine safety professionals would tend to agree are not life threatening or situations that really warrant above ordinary mine emergency kinds of responses. We've had the same experience here in West Virginia. About 90 percent of those that have been called into our system were of an unplanned roof fall or some minor to moderate damage to hoisting equipment.

We have made a change in our state requirement to effectively carve out those two occurrences, so you don't put that kind of a volume and strain on a system that you want readily available 24/7 to respond, react to true mine emergencies. That change was filed in a revised rulemaking here on the state level about a week ago. I will also provide that for your review and your consideration.

We're also in the process of evaluating the appropriateness and effectiveness of safety shelters on a firsthand basis here in West Virginia mining operations. We've advocated the creation of and are participating with the Mine Safety and Technology Task Force. Again, this task force is charged with evaluating and proposing for industry use improvements and advancements in mine health and safety, miner tracking systems, and also, new mine communication systems. Again, we would urge that you work closely with this group to the extent that you can get together as mine health and safety professionals and develop uniformity and consistency within both the federal ETS and the state requirements would certainly be welcomed by the mining community here in West Virginia.

I also want to observe that just last Friday, the state, once again, took bold action which our association supported, and established new requirements to have eight additional mine rescue teams fully equipped with all the listening and detection devices here within the state, hopefully by some time by early Fall, those

-- all those components will be in place, but it was an administrative rule developed by our Mine Health and Safety Board which has been an arm of the legislative process here in West Virginia. Both management and labor representatives participate. The Board has been in effect for some 30 years now and has a record of quickly responding and reacting to mine health and safety issues here within the state. It's not intended to supplant any existing mine rescue function, if you will. It's intended to provide a fully -- compliment trained and staffed complement of mine rescue capabilities on the state level, to supplement those that are currently implemented and exist through company programs.

So, with that, I'll conclude and just express our appreciation for you coming to town, giving us the opportunity to comment on these rules, and we look forward to working with you again in our pursuit of making further improvements to our overall mine safety performance record here in West Virginia. Thank you.

MR. SEXAUER: Thank you. Any questions? No? May I have those two documents that you mentioned? Thank you very much.

Just for the record, I'll note that we received three documents. One is the West Virginia Coal Association comments. Another one is on NMA stationary, the testimony of Bruce Wattsman before MSHA. And, another document, West Virginia Secretary of State Law Division, Notice of an Emergency Amendment to an Emergency Rule. So, we'll put those into the record.

Okay. Our next speaker -- we have, I guess, three members from the United Mine Workers. Will they be -- will you all be speaking together? Ron Bowersox, J.R. Pastey, and Gary Trout.

MR. BAKER: Actually, Gary had to go to town and I guess the rest of the group is gone, so I'll sit in, in their stead, if that's all right.

MR. SEXAUER: Sure, absolutely.

MR. BAKER: I guess it's this microphone?

MR. SEXAUER: Yes.

MR. BAKER: Okay. My name is Tim Baker, that's B-A-K-E-R. I am Deputy Administrator for Occupational Health and Safety for the United Mine Workers. I have already commented fairly extensively on a lot of the emergency standard but would like to make a few other comments for the record.

First of all, you know, I've got to point it out, I find it ironic that almost without exception, at the three hearings I've attended and also the hearing in Denver where I read the transcript, that universally, mine operators say how they support the idea and they support the emergency standard, and then they subsequently, piece by piece, tear every section of the proposed regulation apart, which I think should be of real concern to all of us. You begin to wonder which statement is, in fact, the truth, and I think as we look at the comments that have been made, that it's not difficult for me to figure out which is the truth, and just as a couple of for-instances, the 15 minute rule causing confusion is inconceivable to me whenever at the same time we discussed and continue to discuss the problems that miners have donning self-rescuers, but it's not going to be confusing teaching them how to don two or three different units, but it's going to be confusing for the mine operator to report to the Agency within 15 minutes.

Somehow, here, I believe we have our priorities backward. We still support the idea of a 15-minute notification for any accident, for any fire of any duration, we believe needs to be reported and I will agree to a certain extent that on MSHA's side of the ledger, we need to have some sort of an 800-number where we have employees of the Agency with some knowledge about mining so that they can field this information and get it to the proper individuals to take care of the situation. At the same time, simply having a responsible individual on the surface who doesn't have experience or doesn?t have intricate knowledge of that mine is just as bad on the front end. So, as we begin to discuss how we're going to report accidents, how we're going to report events, it's not sufficient to say "MSHA, you're not doing your job, we can't get through," or, "we can't get the information." I would submit to you that operators have a responsibility to have individuals on the surface who are uniquely qualified to handle those situations, understand the mine, understand the structure, understand how to get a hold of people. So, let's not lay this all on one end of the ledger. Both sides are culpable when it comes to reporting accidents and what events should occur and flow from that.

I would also suggest to you, as I have stated previously, that -- and, for anyone of you who were at the Sago hearings, we got to hear about the expertise of MSHA, and I would agree that in many of these situations, that the Agency does have expertise. So, therefore, as we report accidents, we should defer to their expertise in that 15-minute time frame, let MSHA decide what they need to do at that point. I am not at all comfortable, and I think history shows that I should not be comfortable, with mine operators deciding "should I report? Shouldn't I report?" Let's let MSHA make the decision after the reporting period what action to take. I don't think there's a miner who has been involved in any of these things who is comfortable with the mine operator making a decision over the course of two hours when there's a fire, or two and a half hours when there's an explosion, "should I notify? Should I not notify? What should I do?" Fifteen minutes is 15 minutes, all accidents, all mine fires. I don't think it's too much to ask. I don't think it's complicated. And, lord knows, if that's confusing, that mine operator has a problem. That mine operator has a major problem.

I heard some discussion earlier today, also, and previously about lifelines in entries where there's track or there's haulage and this is a two-fold argument for the mine workers. We are in support of regulations that would eliminate the use of belt air, that would eliminate the three entry system as we know it. The situation becomes very simple. All mine operators, then, play on the same playing field. You have a four entry system, one which is a designated intake escapeway. We eliminate the need to worry about where the trolley line is or what equipment's running up and down that heading, you have a separate, distinct intake escapeway. We don't have to worry that operator A is not competing properly with operator B because one drives four entries, one drives three. We take care of the situation in that manner and eliminate two problems at once.

We would not argue, either, that there is a need to enhance firefighting capabilities and enhance those activities. I was a little confused this morning that there was -- there continues to be this undercurrent that as soon as a 103(k) order is issued that all activity stops and nobody's allowed to do anything and if fire fighting is going on, then MSHA's now in charge, and my understanding of the K order is fairly simple, an d maybe it's too simple, but I think it's the way the system works, is, the K order does not prevent fire fighting that is ongoing. The K order requires plans to be drawn up, and I would submit to you, if the condition is so severe that we are calling in the Agency and that plans need to be drawn up, those plans shouldn't take hours to do. Those plans should be readily available when the individual inspector shows up on site. So, I don't see -- and I continue to hear that from different places that the K order stops everything. I'm unaware of that being the case.

To go over a few of the specific questions that were asked, we have been in favor of and do support the idea of tethering miners who need to escape from an area or a section. The -- obviously, the tethering -- the tethers have to be long enough so that people don't get entangled, whether they're walking or crawling, however that would work, to progress out of the mine. We think those tethers should be located, first of all, at the beginning of the lifeline, which would be the most logical place to have that tether, however, I don?t think it's too much to ask that the tethers also be available at storage stations for the SCSRs, and obviously, those lifelines should go directly to those storage centers, the SCSR storage centers. In the event of dense smoke or limited visibility, obviously, this would be extremely helpful in getting people to those locations. Understanding the need for reflective signs, but the lifelines are going to be much more useful.

We've already talked, previously, that the union firmly believes that in order for the escape drills to be practicable, and we are not, at this point, advocating walking the entire length of the escapeway each quarter, but we are certainly in favor of walking the escapeway, and how we accomplish that, I think, is something that we will comment on broader in our written comments, but we do need to walk those escapeways, and as we said before, the inspector's got to walk the escapeways every 90 days, that's the time to do it. That inspector should be with that crew, with those individuals. That way, we eliminate any possibility of a paper compliance system which does exist in many instances. So, we eliminate that.

We have come to the conclusion since the last time I testified that a reasonable distance for SCSR storage should be considered in a time frame because, in reality, distances mean very little when you're trying to make an escape. The time is of the essence, and we have concluded that SCSR caches should be in every mine at 30 minute intervals, and those distances will obviously vary based on the height of the coal seam, but it seems reasonable to us that 30 minutes is a long enough distance to have to travel.

We do need to move on, also, to the next generation of SCSRs. I think that that is on the horizon. I think that technology needs to be pushed, here, and this Agency has the ability to and should push that technology for a rescuer that lasts an hour and a half or two hours, or whatever that may be. We need to push for those things to occur.

Records for SCSRs. I've got to believe that most of this information, whether it's the total number at the mine, the manufacturer, the serial number, the -- I mean, it's got to be on a computer somewhere. This does not seem to me to be overcomplicated for them to transfer that information from the mine office or the corporate office to the MSHA district office that's responsible for that mining operation.

One thing I would also suggest, since it seems important to us, is that the sale or purchase of SCSRs, whether you purchase a mining operation as has been done in many instances, for instance, central Pennsylvania, where the mines were purchased and then subsequently closed down, those SCSRs that are transferred, that information should be very quickly sent to the Agency so we know where those units are, and that tracking information should be readily available. This is not a complicated -- I don't think it's a complicated function.

The other thing that I commented on to some extent, and is something that concerns us greatly is the idea of what we're calling a safe haven. I believe, as I stated before, this gives miners a false sense of security. If we're dealing with a safe haven that has a door on each end of the cross-cut and some SCSRs in between, this is in no way a safe area. When the door opens, if the air outside is contaminated, the air inside quickly becomes contaminated, but I think just the structure itself lends itself to the idea that "oh, this is a good place to be, I can either wait here or I can take my time changing out my SCSR," so, safe havens, in our opinion, just are not the solution. If you're going to be a ball kit seal, if you're going to put submarine doors in it, if you're going to have positive pressure, then in reality, you may have a safe haven there. That may be the truth.

One thing I would caution against is, we go down this road and we put a safe haven at the head gate of a long wall panel that's 20 -- going to be 20,000 feet long, we soon have no access to that safe haven. It may well be a very good protectionary for the SCSRs, and that's the investment that operators are making at this point, that that may well be the case, but it's not a safe investment for the miner. We are looking into safety chambers, rescue chambers is kind of a bad terminology, I think, and as we look at those particular pieces of equipment, there are a variety out there. We need to be very careful as we go through that. I was glad that the individual who was -- who I was told was going to go -- come here and speak about the one he built in his garage didn't arrive. We need to have some very specific parameters when we deal with safety chambers. These things need to meet certain standards and we can't have a -- we need to have a prescriptive solution to that. To allow too much flexibility will lead to the least common denominator, "what can I get cheapest that I can live with and the Agency will accept?" I think we need to set some parameters there. And, we will be dealing with a couple of those in our written comments that we've had a chance to really look at.

Another issue that we need to deal with, I think, and there are several that seem germane to the issue but kind of got missed in the rule. We do need to revamp and revise, and really, revitalize our mine rescue team and our mine rescue team concept. There are not enough, despite what anybody says. There are not enough. I think that some of the recent problems that we've had in the mining industry indicates that we can wear these teams out fairly quickly. Not only is it dangerous and stressful, these are long hours and long periods of time, and we need to look at how we expand that nucleus of mine rescue team members, and perhaps, in some instances, I think has been suggested by some senators on Capitol Hill, give some incentive to increase that capacity. But, we need to look at those things.

We need to also look at how we deal with small mines. I want to be careful about how I define small mines and a small operator. Small operator is not an operator who runs 20 mines with 20 or less people. That's not a small operator, okay? They may have a small operation, but they're a larger operator than most would think. They don't necessarily fall into a position where they get this small operator caveat, and -- at least from our perspective.

But, we do need to address how we deal with those, whether we have one or two individuals on site with mine rescue capabilities and understanding of the particular mine, and they need to be readily available, and mine rescue teams, then, from the closest mine that has a mine rescue team, not from god knows where, you know, two and a half hours away, or from the closest facility that has a mine rescue team arrives, they can be on site and they can brief and they can get things ready.

Beyond that, our position is, the Act is clear that mine rescue teams are required. Two mine rescue teams are required at all operations when men are working underground. Readily available, in the opinion of the United Mine Workers, means that if you have a mine rescue team and the members are on midnight shift and it's midnight shift, that team is not readily available. Therefore, two other teams must be available. That is a clear understanding of the act. It's not complicated, it's not difficult reading as some things are. So, that is what we are looking at. We need to revitalize the entire system.

I believe that should be pretty much the end of our comments for the record, at least at these hearings, and hopefully, we will be given the chance to have hearings -- additional hearings either in Washington, Pennsylvania, Morgantown, West Virginia, and Tuscaloosa, Alabama, would be a good place. These are concentrations of large mines and those individuals need an opportunity to speak, and I realize people can say "we came to Charleston, Tim, and we were in the coal fields." The membership of the mine workers that attended today have a six hour round trip. Now, that may not be a hardship for me because they pay me to travel and they pay me to speak, and I don't have to worry about getting dressed for midnight shift tonight, but that is a hardship for miners. That's -- it is not, in our opinion, proper to have hearings this way. I have heard and you have heard, and everybody's heard from operator after operator, and you've heard from me more often than you need to, but the reality is that they, the operators, like I, that's my responsibility for the day, and at the end of today, my day is done and I prepare for the next thing I'm going to do tomorrow. The miners sitting in the back of the room will prepare for their midnight shift tonight. It's not the proper way to run this operation. The concern, the charge, the responsibility of this Agency is not the mine operator. It is not the mine operator. It is every miner who goes to work every day. They need to be heard. To this point, few have been. We need to correct that.

In closing, I've got to say one more time that flexibility is a right. Flexibility is something you earn. Flexibility is something this industry has not earned. If it's not prescriptive, if it's not demanded, those things will fall by the wayside. Those things will not occur. This industry is no more capable today of policing itself than it was in 1968. That's a sad reality of the situation. That is what we deal with. So, flexibility has, as I've said in the past, allowed for belt air, allowed for diesel generators in underground coal mines, allowed for three entry systems and two entry systems. These things aid production, these things increase profit, these things do not -- absolutely do not enhance the health and safety of any coal miner in this nation. We need to listen carefully to what flexibility really means. They have not earned it, they don't -- do not deserve it.

If there are any questions, I'd be more than happy to answer any questions you have.

MR. SEXAUER: Any questions? Okay.

MR. SHERER: Mr. Baker, you talk about spacing the SCSRs at 30-minute intervals. Any suggestions about how do you determine that 30 minute interval?

MR. BAKER: Well, I guess, and part of that process would have to be with the -- with, at least to a certain extent, the escapeway drills that you're going to do, and as I said before, I?m not advocating having somebody start at the face and walk 10 miles out of the mine. We may need to do this incrementally, but that would at least be a beginning test of how far from the face to the first cache you need to be.

I'm not so certain that the NIOSH heart rate study is effective. To be honest with you, I'm not that familiar with it, and, you know, most of the math, here, confuses rather than clarifies. But, I think that we're not that far away from being able to do that. I think there's some semblance of the people of the experts not only in this room but other agencies or with mine operators and miners, that distances shouldn't be that hard to figure out to get to 30 minutes. I think, sometimes, we try to create so much science around a subject that we lose track of the simple "how can we walk this thing, how do we walk it and how long is it going to take?" Some of it's simpler rather than difficult.

MR. SEXAUER: Thank you, Tim.

MR. BAKER: Thank you.

MR. SEXAUER: Our next speaker is Rick Abraham from the Rio Group.

PARTICIPANT: We're having trouble hearing.

MR. SEXAUER: Okay.

MR. ABRAHAM: Well, I'll pull this mic up a little closer. Can you hear that?

PARTICIPANT: There you go.

MR. ABRAHAM: My name is -- let me get it a little higher. I'm Rick Abraham. I'm from Logan, West Virginia. I have about 38 years of underground mining experience. Since 1974 I have, at all times, been part owner and operator of coal mines.

In my 38 years of mining, I have had the privilege of, at all times, work above drainage, or what's commonly referred to as mountaintop mining. I have never detected any measurable amount of methane, either with machine-mounted monitor or hand-held monitor, in any coal mine that I've ever owned or operated, or, in fact, actually worked in.

Before I move forward, I would want to say one thing. The judicial branch of government is somewhat -- the branch of government that is tasked to interpret our laws. That is not a privilege given to the executive branch, as seen with abortion or prayer in schools. A federal judge in Florida may determine abortion's legal in Florida. It has no relevance in West Virginia. With that being said, whatever rules you do come up with, they should be clear, concise, and be very careful to avoid language that uses phrases like "approved by Directors," that opens them up to interpretation and different interpretations by district, by district manager, by supervisor, and even by inspector. That is not a privilege that MSHA has. These are not that complex. I would implore on you to train your personnel whatever the rules are that they be trained and that printed information be given to the industry so that they also have a clear understanding of what we're tasked to accomplish.

On the issue of SCRs, with it being said, that in the mines that I operate, it is just as likely to have a fire as in any coal mine, but I would disagree with those that would say I have the same likelihood of explosion. Because you do not have the authority to control commerce, and you should not have, there is an issue with compliance. I would submit that you, one, either reduce the standard for outby SCSRs and change the time frame for this reason. When I placed my order, I was told "don't even think about them for a year." I just heard the lady with CONSOL, and god bless them, not only do they have what you're asking, they have more.

If it is the belief of this panel and the consensus of the miners and the industry that all miners are entitled to more than one breathing apparatus, then without your ability to control commerce, I don't know any other way for you to ensure that every miner at least has two before some have 20. I don't know the urgency in a mountaintop mine to store additional, additional on top of each other. I would also suggest that more of a concern for me would be those who most need them, get them, and I don't think that's actually my company. I think that's those deep in the earth who have methane should get theirs first. I believe you can control that by either removing some of your proposals for more than just in the face with a time frame. Once that's accomplished in a manner, that then you can bring forward the next rule that would allow more and more and let everybody come into compliance in the same fashion.

I think there's been a mixing of phrases like "safe houses" and a company coming forward and saying "we would like to store them in a safe location." They were not suggesting that -- sharing those in a primary and a secondary escapeway would somehow be compliance with your proposed rule for a safe house in a coal mine. I would suggest, they should be able to do this along with sharing of the rescuers in a wall. Those that oppose it presume that the air is -- the air quality is good on one side and it's not good on the other side. That's not at all a good assumption, especially if someone's suggesting the temperature's 1,000 degrees. If the temperature's 1,000 degrees, I would suggest it's more likely that the quality of air and the temperature would be more likely on both sides of the wall, and if we're dealing in thousands of degrees, we've got catastrophic problems to start with.

It's sort of ironic that he mentioned that something would be built in a garage, because I, in fact, have built a box in my garage or my shop with less than one hour research on the internet and a couple hundred dollars of materials that may have been thought to be exotic years ago, but due to the space program, are just common, for $6.00 a square foot, I was able to build a steel box that would be placed into a wall 24 inches thick, would store 120 rescuers, and when tested, I maintained the door temperature at 500 degrees by blowing on it with a gas turbine for over two hours, and the temperature in the box was less than 100 degrees. The box was empty. I did not have the rescuers to put in it nor did I put any mass into it, but my recollection from thermodynamics from college years ago would suggest, had their been mass inside that box, the temperature would have been much less.

Also, the standard which you have set is basically none. I could just as well store my self-rescuers in a cereal box so long as I paint it with fire retardant paint. Those that have come forward suggesting that by combining them, not only would it release for other operators like myself to gain rescuers that otherwise may not get them, you have no standard to protect them from roof fall, rib fall, temperature, moisture, movement, location. All of these things would be improved by placing them between two walls or placing them in a box accessible from both sides that won't get up and walk off on the third shift because of a miscommunication between foremen, and now, nobody knows where the box is at.

The question should not be "is it allowed," the question I have of you is "why is not mandatory?" That's the question. Not "should we be doing it," it's "why are you not requiring us to put them between two walls, put them in a box in a stopping that won't move, and protect them?"

In fairness of full disclosure, my mining company did start a subsidiary for the purpose to research, develop, and sell a lifeline. I don't want to really discuss that issue, other than just let you know that it is something I'm doing, and I have some interesting results, but it's nothing that I want to share today.

My brother was a highly trained military pilot who was trained to fly in all weather conditions, and I did that with him. The disorientation by no visual contact or any reference -- of course, it was also enhanced by no real sense of gravity up or down, but you had no reference on the compass of where you were at, is frightening. For the same reason that highly trained pilots look at their instruments that tells them they're flying straight and level but will turn their planes and fly them into a mountainside is the same thing that you need to give a lot of thought to when miners are in zero-visibility conditions. It's not just so simple to go over there and grab the lifeline and find your way out. If you could find it, it gives you hope. I've heard nothing that would suggest anything that's going to help me go find it. I can tell you what doesn't work: a strobe light.

On the issue of smoke machines, if anybody's looking to just -- for a small room or what I've built, there's a number of theatrical smoke machines. The one I bought was $300.00. They're readily available at Mac and Dave's, any music store has them, they're on the internet, they're theatrical smoke, latex, they're safe to breathe. The bigger machines are also on the internet. A lot of people have got them.

One thing, there seemed to have been some criticism in Logan about the fire department and their involvement in one of the recent disasters. They do have a technology that's thermal imaging. I have taken the camera underground. Some of the results are interesting. It's not the sole answer, but it's something that MSHA should look at and give major consideration. I've tested lights, laser beams, smoke is tough to look through. Thermal imaging can do it. It can be used to guide vehicles or people to safety. It would be unconscionable to stop and say "buy 16 rescuers and everybody's happy," and go away until the next disaster.

One thing, I guess it's FOX News and the publicity that the last two disasters just happened to be smoke and fire, but had it been a couple years ago, it was an inundation of water. That seems to be off the headlines today.

The other thing that I?m a bit confused about, and I don't even know if you have the ability to fix it, there seems to be -- we've used the word SCSR in law and that, by definition, defines what it is that's available to me. When I went to the fire department, the guy pulled up an apparatus that's available today, it would give me two hours of breathable air, a full face shield, I can speak with it on, I can replenish the air in it without taking it off and donning it and switching from one brand to another, but it's my understanding it was a matter of law, these things can not be considered because the law was written and defined what a breathing apparatus is. I would suggest that the SCSR would be a device to get you to something else, and once you get there, the world should be open to new technologies and new ideas.

I guess that's the same reason I'm not a member of a mine rescue team, but it's my understanding, that's not their device their choice when going back into ruined environments, where the air is not breathable. That is not the device they choose to wear. Now, there is a reason for that. MSHA should look at that, and if the law is wrong, then it should go back to congress if you don't have the ability to fix it, then we have a congress that has the ability to fix it.

And, with that, I'll get off my soap box and I thank you for your time.

MR. SEXAUER: Any questions? No? Thank you.

Our next speaker is James Szalankiewicz.

MR. SZALANKIEWICZ: Thank you for this opportunity, and after sitting back there all this morning, I'll try to keep up close and talk loud.

I am an owner/operator in Western Pennsylvania, four small underground coal mines. Three of them are low coal, one of them is a little bit higher. And, the low coal I am defining as 36 inches, and the unique nature of a 36-inch coal seams, I don't think has been intentionally neglected, but I think they have to be recognized, 36-inch coal seams. And also, the unique nature of a small coal mine and, as I said, our mines are relatively small, one production unit in it, the mines are in the upper Freeport coal seam, ingress and egress as by method of a three-wheel, battery mantrip, permissible and nonpermissible, depending on where they're used. Those are how the men go in the mine.

As an owner/operator, I do not want to see any type of injuries. Knee injuries are, by far, our largest reportable accident, and they can be chronic, so we do everything in our power to make sure that the man in the mine gets a ride to wherever he's going, a ride back out, or any examinations. The only place that a worker for us is on his hands and knees, and in 36-inch coal, make no doubt about it, you're on your hands and knees, is in the working place. The mantrip is, basically, outby area and they ride in, leave their lunch there, and do their work.

Our primary escapeway is also our way into and out of the mine. The men coming into the mine ride in that entry -- escapeway or intake, main intake way, and ride out every day as part of the routine. They are riding a three-wheel mantrip, either permissible or nonpermissible, depending where they need to go.

Our entire -- our secondary escapeways are all in our belt entry directly adjacent to our primary escapeway, our main intake. The beltway is separate air course and again, it is our secondary escapeway. One is adjacent to the other. Any of our mines, you can also ride a three-wheeler the entire length of the secondary escapeway, around belt drives, the whole way out. They're designed that way because I recognize as a fact that the more our gentlemen crawl, our coal miners, the more injuries they're going to have and the more likely they're going to get hurt. So, again, we groom the mines so there's no place or no duty other than the actual loading coal that the man can not get there. Weekly return runs, they're all traveled on a three-wheeler.

But, one of the major concerns I have is the idea of our men having to crawl a mile and a half, two miles out of a 36-inch coal seam. As I said, our biggest injuries is knee injuries. We've been involved in multiple studies over the past several years with NIOSH and with MSHA from the District 2 office, evaluating different types of kneepads, different techniques, different snake oils, anything we can to keep these gentlemen healthy and keep their knees healthy, and for me to ask my men to go through the exercise of leaving that perfectly good mantrip there and crawl two miles out of a mine, it's very, very foolish. I'll make the prediction right now, for the record, that if I'm required to have my men crawl out of that coal mine, my lost time accidents are going to more than triple. At least, more than triple. It just isn't conducive.

Again, bear in mind that the characteristics and the environment of these mines are all dedicated around being able to ride in and ride out, and there is generally multiple sources of transportation. There's probably two vehicles for every -- you know, two options to get in and out of the mine, so I'm very, very concerned of that idea of having to crawl in and out of the mine. It just does not make any sense. Certainly, I want to be familiar with the escapeway routes, but they're very simple. You know, one entry in, one entry out.

So, I am very concerned about that portion of the proposed regulations. None of our job descriptions in our coal mine involve crawling in or out of our mine. You crawl in or about the working place, you have proper kneepads, any kind of kneepad imaginable, but none of them include crawling in and out of the mine.

With that said, I do -- again, to reiterate, I do not believe we should be required to crawl in and out of the mine.

One thing that I've noticed, and, of course, I?m perfectly aware of it, in a disaster, a mine emergency situation, I agree with what's been said today: evacuation is paramount. Get out of there. I have a somewhat strange situation in the Commonwealth of Pennsylvania. If there is a fan outage in the Commonwealth of Pennsylvania, my gentlemen are required to leave their mantrip there and crawl out of the coal mine, no if, ands, or buts about it. Now, let's couple that fan outage with a possible emergency. With the new regulations, my men are going to carry an SCSR by their side. They're going to have one on the mantrip or the scoop for each of the men. If there is a fan outage and there is an esc -- an emergency, my men have to leave their mantrip and crawl to their death, two and a half miles out of the mine. I mean, it just -- it doesn?t make sense.

Now, I realize the MSHA regulations allow us to do that, but, you know, we're looking at emergency standards, here. I think an emergency standard might be due in this situation that in the case of a fan outage, the men be able to exit that mine. You know, with today's technology, with multiple gas testers, you know, get out, but it's very frustrating to me as an owner/operator.

The lifelines also present a somewhat unique situation in low coal. I'm not saying not to have lifelines. That's not my intent. My intent is, try to develop some way that they're practical in low coal. Again, it's 36 inches and if you have them in your primary and secondary escapeway, our primary escapeway is a route into and out of the mine and placement of that lifeline is going to be very difficult to come up with. You've got to put it some place where, first of all, it will remain in place and not be torn down by a scoop or a mantrip, and you've also got to place it some place where the operator of that scoop or mantrip isn't going to get decapitated. That's why the -- John Gallick had mentioned the possibility, and we have basically asked him to, to consider putting it on the high voltage cable. I realize that that's a -- you know, that's a point of concern, but in our mines, that high voltage cable is one area that nobody ever goes as a rule, and it's always protected. That would be in our primary escapeway.

The second situation is in our secondary escapeway, it's a conveyor belt. From the loading point clear outside, you just keep that belt on your right-hand side, and you're going outside. I'm not saying lifelines aren't practical, but again, put yourself in my operator -- my coal miner's position. There is an emergency, he has to crawl out, carry one rescuer, wear another one, and hold a lifeline. I'm not -- believe me, I don't say that they shouldn't work, but I think the local aspect maybe deserves a lot more consideration than possibly it's getting.

Now, I wasn't at the other three meetings. In fact, I almost didn't come to this meeting because I?m like the gentleman from Pennsylvania, I'm six hours away, but I think that the lifelines themselves do consider -- have to have some consideration of where they could go. I suggest that if it's a belt entry that the belt is in the secondary and it's continuous to the outside, I don't think you have anything more permanent than that, and as far as a primary escapeway, I would like to see consideration to leaving it on the high voltage cable. Again, maybe it won't work, I don't know, but some way, it's going to be a very, very difficult task to keep that lifeline suspended to the roof without having it torn down routinely, and certainly, if it's there, you want to be able to count on it. You don't want to be able to have an emergency and someone assume the lifeline was continuous, you're following it, and it get taken down somehow.

Now, the SCSR issue, you know, I certainly have no problem with that. I hope we never need them, but as one gentleman said, we've all placed our orders now and it's going to be some time before we get them. One of my particular coal mines is in there quite a ways and we're going to have at least two cache areas, and I understand that right now, that the outlook is, you put one in a primary sec -- escapeway and one cache in a secondary escapeway. Well, in our situation, the primary and the secondary are right beside each other. In other words, you can go through a mandoor from one to the other. Now, when I start to get these SCSRs delivered and if I don't have enough to do the entire mine when they come, I would suggest that I do put them in a common crosscut and I do put a stopping on each side and a mandoor on each side. That way, either entry, the gentlemen have, at least for the time being, they could get by both routes. Now, when I do get enough to do the entire mine, my intent there is, you know, basically, I'm going to have one storage area on one side of a stopping for the -- if you need to come out the primary. On the other side, I'll have the other storage area if you need to come out the secondary, and lord help us if we need any more and we're coming out the primary, we just go through the secondary to get them. So, you know, I think the idea of the consideration for -- at least until all the ones that are manufactured are needed -- I mean, are needed are manufactured, some consideration to be given to that outlook of it.

And, now that we're all taking a little closer look at our SCSRs, we're also beginning to think that maybe we should be getting rid of some. We're losing some through attrition, by looking at them closer, so that's also going to be a little bit of problem on the supply. But, we're prepared for it, so we've made our orders and there's good storage units out there on the market, and we'll put them in there when they come, but my purpose is to make sure that, fellows, we don't -- and I'm not sure what the other meetings were like, if any low coal operators spoke, but we are in a unique situation. I'm sure there's nobody at that table could, you know, crawl two miles out of a mile or one mile out of a mine, and I know you've heard that, so I would like to have -- go on the record as I think that the evacuation plans should be allowed to be ridden out of the mine. If we don't, as I said once before, you're going to see my accident -- lost-time accidents go up drastically.

But, I do want to thank you gentlemen and lady for the opportunity. I said I didn't really intend to come and I apologize for the informal nature. If I thought I was going to speak, I'd have written something up, and I will follow up with a hard copy, but as I listened to the meeting today and I heard very little concern about my application with low coal, I thought I'd like to get on the record with that and maybe get a little bit more attention if at all possible.

Any questions?

MR. SEXAUER: Do you have a question?

MR. FORD: Sir, since your mines are small, like you said, do you operate one shift per day?

MR. SZALANKIEWICZ: No, some of them are two shifts per day. Some are two shifts a day. And, with the new regulations, with the amount of SCSRs, we will be staggering them so I don't have to double it one more time. They won't be, you know, hot changes. I will have one crew come out of the mine, the other crew go back in the mine, which is no problem, but it will save me doubling the SCSRs one more time.

MR. FORD: Okay. On average, how many workers are in -- on -- per mine?

MR. SZALANKIEWICZ: In -- on the average, on a two-shift operation, I have about 25 men. On the daylight shift with a super, the mine foreman, major foreman is there, it would be slightly over half. On the afternoon shift, they're slightly less than half.

MR. FORD: Okay. So, you've got about 12 men on a shift?

MR. SZALANKIEWICZ: Yes, sir. Approximately. A matter of fact, our storage plan, I think we're -- we designated 15 at each cache. That way, we were certain to cover the guys in the mine.

MR. FORD: Okay. I've just got one more question.

MR. SZALANKIEWICZ: Sure.

MR. FORD: On your ordering purchases for SCSRs, --

MR. SZALANKIEWICZ: Yes, sir?

MR. FORD: -- can you tell me what kind of SCSRs you --

MR. SZALANKIEWICZ: We've been doing them --

MR. FORD: -- have been ordering and about the average price?

MR. SZALANKIEWICZ: We have always used the CSEs. We're happy with them. We -- when I first went in business about 15 years ago, we considered a W-65, but we said, "let's just go with the self -- it's there, it's good for an hour," and when we first started buying them, I don't mean to indicate that the economics are going to dictate over safety, not -- that's not my intent, I don't think there's anybody in this room that isn't here to improve mine safety, but when we first started buying, they were around four and a quarter a piece, now they're $600.00 a piece, and I'm -- support, you know, capitalism, supply and demand, they're probably going to go up some more, but to me, that has nothing to do with mine safety, and I don't think any of the other mine operators have that problem either. We certainly want to get any type of consideration, and again, I do feel that keeping in the same cross-cut, in our unique situation, would not be a problem, but, you know, we'll do what you guys need us to do, but if I do have to put them in separate entries, I am going to put them one on each side of a stopping with a mandoor. If the guys need them, they're there.

MR. SEXAUER: Thank you, and thank you for coming the distance to speak to us.

We've covered all the speakers that have signed up. Is there anyone else in the audience who would like to address the group?

I'd like to express my appreciation on behalf of MSHA to all of you who participated today at the public hearing and your comments and testimony will help us develop a final rule that provides the most appropriate and effective protection for miners and we'll take into consideration all the comments and testimony that we've heard. So, thank you once again. This hearing is adjourned.

(Whereupon, at 2:13 p.m., the proceedings in the foregoing matter were concluded.)

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REPORTER'S CERTIFICATE

CASE TITLE: Public Hearing on MSHA's Emergency

Temporary Standard for Emergency Mine

Evacuations

HEARING DATE: May 9, 2006

LOCATION: Lexington, Kentucky

I hereby certify that the proceedings and evidence are contained fully and accurately on the tapes and notes reported by me at the hearing in the above case before the

Department of Labor.

Date: May 11, 2006

Kristopher Robert Kaun

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DOCUMENT 19

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

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

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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

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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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DOCUMENT 20

bhpbilliton

New Mexico Coal
San Juan Coal Co.
P.O. Box 561
Waterflow, NM 87421

March 13, 2006

Mine Safety & Health Administration
Office of Standards, Variance & Regulations
1100 Wilson Boulevard
Room 2350
Arlington, VA 22209-3939

RE: RIN 1219-AB41

Dear Director:

San Juan Coal Company has completed our review of the Mine Safety & Health Administration Request for Information regarding Underground Mine Rescue Equipment and Technology and is pleased to provide the following comments for the consideration by the Agency.

We have also solicited information and comments from BHPBilliton coal mining operations in South Africa and Australia. This information has been incorporated.

San Juan Coal Company is pleased to have the opportunity to provide these comments.

Sincerely,

David Hales
Health & Safety Superintendent
San Juan Coal Company

Our comments and answers to the questions contained in RIN 1219-AB44 are as follows:

A. Rapid Deploy Systems
RESPONSE:

Seismic systems are available that could serve the purpose. We do not have the technical information at present. Information from the oil and gas industry indicates that equipment is available that can pinpoint locations within about 10 feet.

Due to the extreme distances between underground mines in various parts of the country, the challenge would be to have these systems in a rapid deployment situation. In New Mexico for example, equipment stored in Albuquerque could take as long as 4 hrs to be delivered to Carlsbad or Farmington.

In South Africa the government provides emergency drilling equipment for the purpose of drilling rescue boreholes such as the one used at Quecreek. A test of this system at the Khutala Colliery was successful in reaching miners in a refuge bay within 9 hrs.

Ideally such seismic and drilling systems would need to be stored in each state where underground mining is conducted in order to be of value in the first minutes or even hours of an emergency event.

B. Breathing Apparatus
RESPONSE:

San Juan Coal Company currently equips, trains and maintains 3 mine rescue teams at its underground coal mine near Farmington, New Mexico. There are 23 team members. These teams are equipped with Biomarine SCBA equipment.

BHPBilliton underground coal mining operations in South Africa and Australia currently use the Draeger BG-4 apparatus.

C. Self-Contained Self-Rescuers (SCSR)

RESPONSE:

1- There is new technology that could be effective in protecting miners. Ceramic devices can filter oxygen out of a contaminated atmosphere and deliver it to a person. These devices would not function in an oxygen deficient atmosphere. There are also some rechargeable systems employed in other parts of the world. Refill stations are positioned at strategic locations for miners to recharge their device. These stations could become damaged or destroyed in the event of an explosion. In that event, the miner may reach the location expecting to be able to refill his tank only to find that the system has been destroyed.

2- Development of an SCSR with a longer duration may be desirable. The problem is that the duration remains a finite period of time and may not be sufficient in a given situation.

3- Mine operators that have implemented SCSR Storage programs already have extra units available in additional caches. In the case of San Juan Coal Company, any working section that takes longer than an hour to walk out of is supplied with an additional cache of rescuers along the escapeway route. These storage areas are currently marked with reflective signs. Recent changes to New Mexico State law will require the signs to be luminescent and supplemented with strobe lights.

4- We have no evidence to suggest that SCSR units need to be inspected more frequently. Our SCSR devices are inspected by the user each shift. Our stored units are inspected every 8 hrs as part of the regular onshift inspections in the mine. These inspection frequencies are detailed in our SCSR Storage Program.

5- We have no evidence to suggest that the SCSR service life should be different than those terms currently established for each unit. Those periods of time should continue to be determined through testing by NIOSH, MSHA and the manufacturers of the devices.

D. Rescue Chambers

RESPONSE:

1- San Juan Coal Company has implemented the use of chambers we refer to as refuge chambers. These are constructed as semi-permanent facilities, supplied with fresh air from the surface via a borehole. The chambers are supplied with food, water and other emergency supplies. The chamber is provided with two communications systems. One is connected to the existing mine system, the other is from the chamber to the top of the borehole.

We continue to train our miners to escape in the event of an emergency and provide multiple escape routes from each part of the mine. We added these chambers to provide another alternative in the event that escape is cut off.

Regulations currently in effect would allow the Assistant Secretary to require these facilities now. The decision to require them should be based on the risk profile of a given mine.

The use of refuge chambers makes much better sense than trying to determine the appropriate quantity of SCSR units necessary to maintain breathable atmosphere in the event of an emergency situation. The numbers proposed in some of the recent US legislation are excessive and impractical. Miners couldn't carry the 16 units proposed by one bill. The other bill proposes a requirement for mine operators to provide 4 days of breathable air for each miner. These recommendations do not appear to based on sound, mine specific risk assessments.

2- Our refuge chambers are not mobile. Information collected from other countries indicate that if a mobile chamber is large enough to accommodate the number of miners in a given working section, the unit is commonly destroyed trying to move it from one section to another. If the system is required, the decision to make them permanent or mobile should be left to the mine operator.

3- If a mine operator builds a place for miners to take refuge, there should not be a finite supply of air. The supply of air being delivered to our chambers has been calculated to be able to support 200 people indefinitely.

4- The numbers of people that the chamber should support should be based on the numbers of people working in a given area. Chambers used in South Africa are designed to accommodate from 30 to 50 people. This is based on the numbers of employees assigned to that part of the mine.

5- South African and Australian standards have been developed based on each mine's risk profile. Some mines have the chambers as close as every 600 meters and others have them up to every 1,000 meters or more. This spacing is determined based on the miners wearing a 20 minute SCSR and storing their 1 hour units in the refuge chamber.

If required in the US the spacing of chambers should be similarly assessed by the mine operator and the spacing for each mine determined by that operator.

E. Communications

RESPONSE:

1 thru 8 - Wireless communications systems might be capable of enhancing communications during mine rescue operations provided the leaky feeder or beacons involved are not damaged by the event creating the rescue situation. In an event such as Sago, if there had been multiple communication systems, those would likely have been destroyed as well.

Improving the capability of knowing where miners are located during the shift would be desirable. Some primitive systems are available now that would provide limited information about when people passed a certain point and if they had passed another beacon somewhere else in the mine. Their ability to pinpoint miner's locations is extremely limited at this time.

We have sought information about such systems and have been informed by the manufacturer's representatives that these systems require power from the mine's electrical system. In the event of a fire or explosion this power is likely to be removed from the mine. The available battery backup systems are currently not MSHA approved and would therefore add an unnecessary ignition source risk.

Fortunately there is better technology on the horizon and MSHA should take steps necessary to expedite the availability of these improved systems. Approval applications have been filed and should be completed as quickly as humanly possible. San Juan Coal Company stands ready to include this technology into our systems and have offered to be a beta test site as this equipment becomes available.

San Juan Coal Company utilizes four separate communication systems. The mine is equipped with a leaky feeder radio system that is used as the primary communications system. The MSHA approved radio that we currently use is no longer being produced. At present we do not have a replacement radio identified. That replacement will also need to be MSHA approved.

The radio system is backed up by a standard pager phone system. The pager phones are primarily located along the belt lines and other outby locations. It is also used in the working sections and in our refuge chambers.

San Juan Coal Company has also installed a digital telephone system to some parts of the mine. These are not widely distributed.

San Juan Coal Company also utilizes a PED system. This one-way system has an antenna installed on the surface and provides the capability of sending text messages to persons wearing PED receivers. There are approximately 140 miners wearing these receivers.

The PED has successfully accomplished the objectives we set. It does not provide 100% certainty that when you send a message, the intended recipient will receive it. Messages do not get received if the person is inside a vehicle or under other large steel structures, such as the shields. The individual receivers are very high maintenance and are easily damaged in the mine environment. System reliability is typically compromised during lightning storms.

San Juan Coal Company contacted the PED supplier about the availability of a 2-way PED and was informed that due to the power supply needed, a 2-way PED was not possible. Other technology is being developed that could accomplish this 2-way communication.

F. Robotics

RESPONSE:

We believe there are better systems available to collect gas readings from remote sites. San Juan Coal Company maintains a Tube Bundle System that is constantly performing these tasks.

This system constantly pulls air from up to 30 different locations underground. Many of these locations are from places people cannot go such as behind seals. This air is analyzed and trends monitored. The system provides alerts and alarms in our Control Room as the situation warrants.

The ability of robotic systems to cope with the mine conditions needs to be improved before expanding their use. It appeared that the inability of the robot actually added to the delays of getting the Sago Mine explored.

G. Thermal Imagers and Infra-Red Imagers

RESPONSE:

San Juan Coal Company maintains thermal imaging capability at this mine site. This equipment is used when conducting maintenance examinations.

It is also intended to be used if a suspected spontaneous combustion event begins.

This equipment is utilized under safety provisions defined in a Petition for Modification.

H. Developing New Mine Rescue Equipment

RESPONSE:

Items 1 thru 5 - The major complaint heard about approval of new equipment is that it takes so long. We've seen this with field modifications, petitions for modification and heard of these problems from suppliers that are trying to get new products to the mines.

Equipment used for mine rescue needs to be intrinsically safe. Mine rescue team members must never be placed at risk by using products capable of causing an ignition or explosion.

Anything that can be done to streamline the process should take place immediately. If additional personnel or funding is necessary to make that happen then it should be provided.

Our industry is continually faced with the problem of being so small that it is often the choice of OEM's not to invest money in products for mining. This has been especially true with regard to diesel powered equipment. There are other examples as well.

Increased funding should be provided for NIOSH research grants and increased funding should be provided for the former Bureau of Mines personnel now working within NIOSH to assist in developing new technology for the mining industry.

I. Mine Rescue Teams

RESPONSE:

1- Part 49 identifies the basic equipment a mine rescue team should have. This regulation also sets the numbers of persons that make up a team. This needs to change. Mines should be allowed to have teams made up of smaller numbers of people. As is done in South Africa and Australia, the numbers of team members is determined by the hazard being dealt with.

It would be far better to allow smaller sized teams than to continue to let mines operate without maintaining mine rescue capability.

In addition to the types of equipment listed in Part 49 there should be protective equipment necessary for performing the specific tasks assigned, ie turnout gear if being sent in to fight a fire.

2- The equipment required should be matched to the mine size and the risk profile for that mine. It would be much better for a small mine to be allowed to provide smaller amounts of equipment, 3 to 6 sets for example than holding fast on the requirement for 12 sets. This results in having that same mine seek mine rescue coverage from someone several hours away and end up with no equipment on site at all.

3 - If each mine operator maintains their teams, the equipment for the mine rescue station is part of the equipment located at the mine. Mines with their own teams already far exceed this minimum set of equipment. There is no need to make changes to this standard.

4- This equipment should be maintained at the mine.

5- Mine rescue teams that will be involved with fighting fire should receive training specific to that task. This would be the same if they are performing high angle rescue etc.

6- The practice of allowing mines to exist without having their own equipment and personnel trained to perform mine rescue should be halted. Adjustments should be allowed for teams to consist of smaller numbers and the funding for the equipment and training should come from returns of royalty payments, assessments, taxes etc.

7- Updating is expensive. Finding ways to reimburse the operator for these costs through returns of royalty payments, assessments, taxes etc. would improve the pace of updating.

8- New technology should only be used after performing a risk assessment and the risk presented by this new technology does not put mine rescue personnel at greater risk.

J. Government Role

RESPONSE:

1- Require all underground mines to have mine rescue capability on site.

2- Require all underground mines to have mine rescue capability on site.

Adjustments should be allowed for teams to consist of smaller numbers and the funding for the equipment and training should come from returns of royalty payments, assessments, taxes etc.

San Juan Coal Company has no comment regarding how standards and implementation regarding mine equipment and technology could be improved.

3- Provide regular evacuation drills.

At least annually all miners should receive hands on practice sessions at least with emergency equipment such as SCSR units, fire extinguishers, fire hydrants and hoses.

Miners should also participate in Mine Emergency Response Drills.

San Juan Coal Company has no comment regarding what types of emergency supplies (timbering materials, ventilation materials, sealing materials, etc.) should be maintained at each mine site. Current requirements are adequate.

5- Find ways to help fund the small mine operators so that all mines have equipment and trained personnel at their sites.

6- Implement the recommendations described throughout

DOCUMENT 21

MINE ESCAPE PLANNING & EMERGENCY SHELTER WORKSHOP

National Academy of Sciences
Washington, DC
April 2006

F.J. van Zyl

CSIR

South Africa

CSIR

our future through science

Overview

- South African Approach
- Three main focus areas
  - Underground fresh air
  - Getting to it
  - Getting to surface
- Current Practices
- Research
- Potential Needs
- Conclusions

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South African Approach

- Mine Health and Safety Act
  - Hazard Identification and Risk Assessment based (HIRA)
- Emergency Preparedness & Response – Risk Based

South African Approach in HIRA Practice

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Underground Fresh Air – Current Practice

Get Miners to Fresh Air – Rescue Bays

- Hard Rock Mines
  - 30 minutes from work area – based on SCSR duration
  - Rescue Bay requirements
    - Compressed air
    - Water
    - Communications
    - First-aid
  - Sufficient size for deployed workforce

Underground Fresh Air – Current Practice

- Coal mines
  - 1 400 m maximum from work area – DME guideline, based on belt worn SCSR duration
  - Fixed and Portable
  - Fixed
    - Access from surface for rescue – air from surface, communication, water, first-aid and rescue access.
    - If no surface access 24 hours life support - oxygen candles, first aid, water, communications.
  - Portable
    - 24 hours duration, oxygen candles, first aid
    - OEM design (Survive-Air, MARS, etc)
  - Focus on Collieries

CSIR our future through science

Underground Fresh Air – Research

Get Miners to Fresh Air – Rescue Bays

- Most rescue bays designs and layouts in-house based on DME guidelines (fixed and portable)
- Mine Health and Safety Council (MHSC) – Public funding
  - Assessment of the design of refuge bays in coal mines – COL 115
  - Feasibility of using radio-assisted location of refuge bays (REBLE) – COL 224 (cancelled)
  - Manual of best practice for emergency response procedures – COL 605

Underground Fresh Air –Needs

Get Miners to Fresh Air – Rescue Bays

- Guidelines on maintenance of rescue bays
- Clear guidelines on location of rescue bays
- Sealing off of rescue bays
- Use of oxygen candles – fire risk, duration
- Flameproof and intrinsically safe issues – portable units
- Minimum design criteria for portable rescue bays
- Multiple entries into portable rescue bays

Get Miners to Underground Fresh Air – Current Practice

Get Miners to U/G Fresh Air

Assistance to 'section waiting' place:

- Belt worn SCSR based
- All miners in U/G coal mines issued with belt worn SCSR
  - Each miner issued with dedicated unit
  - Provide assistance to rescue bays or long duration caches
- SCSR durability
  - Annual testing program – 1 % of all deployed SCSR tested annually (1 200/annum)
  - CSIR select and test with use of breathing simulator
    - Test criteria O_2, CO_2 and breathing resistance
  - Tripartheid Technical Committee oversee testing – state, OEMs & labor
  - Guidance on technical issues and testing specifications

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Get Miners to Underground Fresh Air – Current Practice

Get Miners to U/G Fresh Air

Assistance from ' section waiting' place:

- Use of long duration units - chemical or compressed air
- Guidance systems
  - Guide rope with directional cones most common
  - Audio systems
- Rescue bays marked – audio, visual and physical
- Issue with enough air to reach 2nd rescue bay (some mines)

Get Miners to Underground Fresh Air – Research

Get Miners
to
U/G
Fresh Air

Assistance to 'section waiting' place:

- Mine Health and Safety Council (MHSC) – Public funding
  - Use of ULF for communication and control following an explosion – COL108
  - Procedures to overcome disorientation and visibility after explosions – GEN 101

Assistance from 'waiting' place:

- In-house and OEM developments

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Get Miners to Underground Fresh Air – Needs

Get Miners
to
U/G
Fresh Air

Assistance to 'section waiting' place:

- Biggest current concern – unofficial statistics on quarterly escape training indicate that up 60 % **do not** make it
- Early warning system – Personal Safety Device (guidance and location purposes)
  - EWAC
  - Belts
  - Aromatic gasses
  - Etc.
- Non-visual guidance vs 'visual' guidance
- Preparedness training – surviving teams usually have brigades men with them
- Use of goggles with SCSR

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Get Miners to Underground Fresh Air – Needs

Get Miners to U/G Fresh Air

Assistance from 'section waiting' place:

- Effective system – engage more than one sense
- Reliability of systems after fire or explosion

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Get Miners to Surface Fresh Air – Current Practice

Mines Rescue Service (MRS)

- Brigade system
  - Volunteer based
  - Region and country wide
- MRS independent organization
  - Rescue co-ordination centralized
  - Brigades men training done by MRS - intense
  - Annual assessment training of brigades men
- Very successful
  - Good track record

Get Miners
to
Surface
Fresh Air

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Get Miners to Surface Fresh Air – Research

Mines Rescue Service

- Continued improvement
- Focus on human physiological response

Get Miners
to
Surface
Fresh Air

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Get Miners to Surface Fresh Air – Needs (Challenges)

- Advancement rather than needs
- Physiological response – heat
- Declining numbers of brigades men

Get Miners to Surface Fresh Air

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Conclusions

- Getting the miner to the 'section waiting' place biggest issue
  - Guidance in high stress no-visibility situation
    - Human response
    - Technology assistance
- Guidelines on 'Best Practice'
  - Rescue bases
  - Withdrawal practices – early warning & guidance systems
- Evaluation of 'Best Practices' after incidents
  - Humans
  - Technology

THANK YOU

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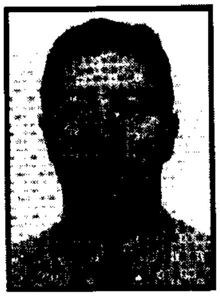
DOCUMENT 22

Survival, Escape and Rescue



Including Factors Governing the Selection of Self-Rescuers and Siting of Safe Havens

J A Forster, CEng, FIMM

SYNOPSIS

The development of an emergency plan as required by the Escape and Rescue from Mines Regulations 1995 is outlined and aspects of the rescue of persons trapped underground are considered. The selection of self-rescuers and, where necessary, safe havens is discussed in detail, reflecting the experience of chemical oxygen self-rescuer wearer trials carried out over the past seven years.

INTRODUCTION

In January 1995 the British coal-mining industry passed into private ownership after 48 years of state control, and with it over 9 000 employees, 19 pits and 32 opencast sites. In 1947 the National Coal Board had taken on the management of over 1 000 collieries and 720 000 miners. In the first year of nationalisation over 600 men lost their lives, 235 in falls of ground and 168 in explosions(1). In 1995 fatalities had reduced to single figures, but accidents and incidents were still occurring at a frequency which required effective emergency planning combined with the unique expertise of the Mines Rescue Service.

From the date of privatisation, the Government had agreed that British Coal would continue to operate the Mines Rescue Service for a period of twelve months. After extensive, and sometimes heated, debate in the forum of the National Advisory Committee on Rescue Work and Rescue Apparatus (NACRWRA) concerning the format of new legislation and function of a post-nationalisation rescue service, the Escape and Rescue from Mines Regulations 1995 came into force on 28 December 1995, establishing a firm basis for a national Mines Rescue Service and placing a clearly defined, proactive responsibility on mine owners for the protection of their employees in an underground emergency.

The Escape and Rescue from Mines Regulations 1995 (1995 Regulations) differ fundamentally from The Coal and Other Mines (Fire and Rescue) Regulations 1956 (1956 Regulations) in that for the first time there is a clearly specified statutory requirement to model the mine safety plan upon an assessment of risk and for effective 'self-rescue' of personnel from the mine in an emergency. Under the new provisions all mine owners are required to provide means of emergency evacuation and rescue. All coal mines and other non-coal mines where flammable or irrespirable atmospheres are a risk must participate in a scheme operated by the national Mines Rescue Service in order to fulfil statutory obligations placed on mine owners for the provision of at least two fully equipped rescue teams located not more than one hour's travelling time from the mine.

This requirement could be discharged by a full-time rescue corps, part-time rescue brigade or a mixture of both.

Certain procedures must be carried out in order adequately to fulfil requirements imposed by Part 2 of the new statutory provision. These include:

- **the assessment of risk;**
- **maintenance of a written emergency plan; and**
- **the selection and provision of suitable self-rescuers and, where necessary, safe havens.**

This paper attempts to identify and clarify some of the issues which may be considered during the evaluation process.

SURVIVAL OF PERSONS TRAPPED UNDERGROUND

The emergency plan requires, amongst other things, the assessment of risk to persons trapped by a fall of ground. Although quite rare, this is one of the most feared and dramatic situations to be contemplated in mining. Such incidents are well documented, as are the successful rescues and tragic failures. Media interest in such an occurrence is understandable. There will be a clear need not only to calm and sustain those trapped underground but also to relay information relating to their condition to their families and the media. It is therefore essential that such incidents are dealt with rationally and professionally. Recognition of the potential risk and adequate contingency planning of mining operations where a second means of

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Paper presented to the South Wales Branch of The Institution of Mining Engineers' meeting on 6 March 1997.

egress is absent will greatly improve the probability of a successful outcome.

The basic premise of all current legislation is to identify potential hazards and minimise the risk of exposure. Roadway collapse in all types of support systems has been sufficiently frequent in recent times to dispel any doubt that it continues to be a very real hazard. Underground support systems in this context encompass self-supporting strata, conventional passive arch- and timber-supported roadways, mixed rockbolt/arch support systems and totally bolted headings and junctions. When such a system fails and people are prevented from passing through the area or are otherwise exposed to danger, this is now classified as a dangerous occurrence under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR 95). That persons are not trapped in the majority of cases is due to vigilance, or where monitoring instruments are provided, to early recognition of adverse trends in roof strata.

Emergency Communication

'In the event that a fall traps people in a heading, rescuers will need to know how many people are trapped, where they are located and how extensive the fall of ground is.'

In the event that a fall traps people in a heading, rescuers will need to know how many people are trapped, where they are located and how extensive the fall of ground is. Communication is vital. The options for providing this are:

- **protection of the existing mine telephone or Tannoy system; and**
- **provision of an emergency radio system.**

Unprotected telephone or Tannoy communication cables are likely to break during a fall of ground. This risk can be reduced by strategic positioning and protection of the cables during installation. Alternatively, a dedicated emergency communication cable could be installed along the floor under a protective cover during development.

Recent developments in emergency underground communication systems include The Trapped Miner Communication System and Mines Rescue Communication radio system, both developed by International Mining Consultants Ltd. The Mines Rescue Communication system (m-Comm) has been developed for use by the Mines Rescue Service inbye of the Fresh Air Base (FAB) and is therefore certified to the highest electrical safety standards(2). The system comprises rugged, lightweight radio transmitter/receivers which can be connected at any point along a light-gauge cable carried by the Mines Rescue team and run off a hand reel as the team advances. This intrinsically safe system has the potential to provide multi-point communication up to a maximum range of 10 km. The radio connection does not involve an electrical joint but is accomplished by an inductance loop clipped around the cable.

The heavy-duty version of this system, called The Trapped Miner Communication System, has the facility to penetrate up to 150 m through solid strata without the aid of a cable or other form of metal conductor. The range is considerably enhanced up to 6 km when a power supply cable, pipeline or similar conductor is available in the roadway. The equipment does not depend upon batteries and can be operated by a manually cranked generator. For the system to be of use an emergency a handset must be maintained near the face of the heading at all times. What must be recognised is that if no system is planned and communication is lost, an extremely desperate situation will confront those trapped and the rescue attempt will inevitably suffer from lack of information.

Emergency Tunnelling

If the length of roadway blocked by a fall of ground is relatively short (say, 5 m to 10 m), direct assault on the fallen debris down the edge of the collapsed roadway may be the best course of action. The presence of passive steel supports may facilitate this in that they often deform in such a way as to maintain a small triangular tunnel along the roadside **(Figure 1)**. If the fall is longer, or more compacted **(Figure 2)**, it may be necessary to break into the roadway side and drive a relief rescue tunnel.

When, on 6 April 1992, at Stillingfleet mine in the Yorkshire coalfield, eight men were trapped by a fall of ground in a coal and stone heading supported by a 'mixed system' of passive steel arches and rockbolts **(Figure 3)** a direct assault on the fall debris was chosen as the best means of releasing the trapped miners. It was most fortunate that the telephone cable survived the fall. Vital information relating to the extent of the roof collapse and conditions inbye of the fall was relayed to the rescue teams and reassurance was given to those trapped and their waiting families. Although rescuers were hampered by fresh roof falls, the men were released unharmed after 15 hrs.

Strong leadership is essential, and once a choice is made everyone must put full effort into making that plan work. This was never more true than at Bilsthorpe Colliery in Nottinghamshire on 18 August 1993, when a massive fall of roof occurred over 46 m in length. In the hours and days which followed, great courage was demonstrated in the effort to release those who had been trapped and died in the fall. When, some 50 hrs after the recovery had started, no further progress could be secured by conventional methods, authorisation to use oxy-propane gas burning equipment was given by HM Principal District Inspector of Mines under section 67(2)(c) of the Mines and Quarries Act 1954. Burning continued under the close supervision of HM Mines Inspectors for over 15 hrs until the recovery was complete.

Inevitably, whichever method or combination of rescue tunnelling methods is chosen, 'hands on' mining methods will be employed at some stage, resulting in the need for ready access to both sophisticated and conventional mining equipment. Such equipment could be maintained at a common holding station by groups of mines or by the national Mines Rescue Service. 'Dig-out' rescue teams have been arranged in South Wales and the Forest of Dean in recognition of the fact that, often, the best people to dig through the fall of ground are those who are most familiar with the local conditions and accustomed to such demanding physical work. Lists of volunteers are held by the Mines Rescue Service, which co-ordinates any rescue work, whether or not it involves breathing apparatus(3).

Emergency Rations

People trapped by a fall of ground should be equipped to survive several days while rescuers tunnel towards them. Dry emergency rations and sealed water canisters could be stored at the face of every tunnel or development heading. Emergency survival equipment is widely available for mountain and sea rescue and could be adapted at relatively low cost for long-term underground storage in suitable containers.

Emergency Ventilation

Pipelines which survive under a fall of ground can be pressed into service to provide another valuable means of communication, sustenance and ventilation. When, during the 1992 Stillingfleet incident, roadway temperatures and methane levels started rising to uncomfortable levels the environment beyond the fall of ground was ventilated through a 100 mm diameter pipe which had survived the roof collapse by use of a small auxiliary fan. This brought considerable relief to the eight men trapped beyond the fall. With that in mind, consideration could be given during mine roadway development to installing service pipelines in such a way as to maximise the chance of their survival in a roof collapse (eg near to the floor at the roadway side, clear of transport traffic). The telecommunications industry has a variety of equipment which will travel through pipes to trail pilot lines prior to the installation of cables. It may be possible to adapt such equipment to perform a similar function in bringing relief to trapped miners.

Equipment has been available to the mining industry for some time which would, it is hoped, tunnel a pilot hole through fall debris. In practice, the probability of success for such equipment is extremely remote as broken rock and steel are very hard to penetrate.

Protection of Auxiliary Ventilation Duct

A fire at the entrance to a development heading affording a single means of egress can trap miners just as a fall of ground can. In such circumstances there is an acute and immediate risk of loss of ventilation due to destruction of the auxiliary ventilation duct. This risk can be mitigated by identifying the major fire risk source—normally the conveyor drive and loop take-up—and installing fireproof steel ducting through this zone.

ARRANGEMENTS FOR ESCAPE

The basic premise of the 1995 Regulations was not that the 1956 Regulations were badly flawed, but rather that the time had come to ensure that standards were not diminished as a result of a lack of co-ordination by independent mining operations. There was a need to formalise existing arrangements and establish emergency procedures for those mines not covered by existing mines rescue provisions—ie coal mines with fewer than ten men, non-coal mines, tourist mines and storage mines. Certain items of equipment held at mines and central rescue stations were also due for replacement, and the new regulations provided a suitable statutory vehicle to facilitate this. When the 1995 Regulations were introduced, it was not expected that they would require significant changes to existing arrangements for escape at the majority of mines. It was, however, recognised that certain locations would present rescue and evacuation problems and would require particular attention, viz:

- **long-length, single-entry headings and coal face districts;**
- **roadways having hot and humid conditions and/or steep gradients;**
- **roadways having a risk of hydrocarbon ingress; and**
- **extensive room and pillar operations employing large diesel-powered plant.**

In all cases a risk assessment is required which must cover all persons at work in the mine, including contractors. Where there is more than one employer at the mine, there is a need for full co-operation between them to ensure that account is taken of each employer's risk assessment. The mine owner must take into account activities external to, and in close proximity to, the mine, either on the surface (chemical plants producing heavier than air products) or at neighbouring mines (eg mines in a complex sharing common airways).

Measures should be put in place to enable persons to escape to safety and protect them whilst doing so. Particular regard should be given to the possibility of fire and explosion. The risk assessment should consider, where appropriate, the presence of firedamp and coal dust, any flammable materials introduced into the mine, such as mineral oil, wood and chemicals, and belt conveyors and electrical equipment.

The risk assessment has to take account of an atmosphere polluted by toxic gases or unable to support life because of oxygen deficiency. Such circumstances may arise following outbursts of gas; where ventilation in narrow drivages is impaired by the inadequacy of the auxiliary ventilation system; where the available oxygen is largely consumed in a conflagration; or from the outflow of blackdamp or firedamp from old workings at times of low barometric pressure.

THE EMERGENCY PLAN

Crisis management is about having the ability to foresee unplanned events and establishing an emergency plan to deal with the unforeseen. This requires commitment and input at all levels by mine owners, managers and employees. It will be necessary to identify those who will play a key role in ensuring that emergency situations are properly controlled and the appropriate resources are available. It is not the intention nor is it desirable to remove personal initiative completely. Indeed, even the best devised emergency plans may not survive intact beyond the first few hours of a crisis. What a well-resourced and constructed emergency plan can provide is an operational framework which will 'jump-start' the emergency response at a time when staff may be in a confused, vulnerable and traumatised state.

'Crisis management is about having the ability to foresee unplanned events and establishing an emergency plan to deal with the unforeseen.'

At large mines having extensive lengths of open roadways or a complex ventilation network it is essential that emergency procedures are worked out in advance using a 'what if' strategy. Primary and secondary escape routes should be identified and made known to the underground workforce. Smaller mines can have relatively simple underground layouts but may not have the surface facilities, manpower or equipment immediately available to support a rescue operation. Suitable contingency arrangements must be made and be capable of being put in place at short notice. Difficulty may be experienced in maintaining suitable emergency accommodation at small mines. Vandalism is a common problem. The Mines Rescue Service may wish to ensure that it has adequate accommodation available to it. Emergency services usually have their own mobile incident control modules and if the mine owners or Mines Rescue Service cannot provide their own, some formal agreement with the police or local authority fire and rescue service may be possible[4].

All these aspects must be considered when drawing up the emergency plan. A good emergency plan should be capable of being put into immediate action, should be sufficiently robust to deal with variations and should identify clearly the functions to be performed by essential post-holders to avoid duplication and confusion. Emergency briefs should be prepared for key staff members:

- **Mine manager.**
- **Incident controller(s).**
- **FAB controllers.**
- **Control room attendants.**
- **Personnel managers.**
- **Medical staff.**
- **Canteen staff.**
- **Baths attendants.**

In order to ensure that those working underground are fully aware of what to do in an emergency

- **underground workers must be issued with instructions on emergency evacuation procedures;**
- **egress routes should be clearly marked in the mine roadways; and**
- **training videos should be shown regularly to remind staff of the essential steps to be taken in an emergency.**

The plan must establish what action is to be taken in the event of

- **an underground explosion;**
- **an underground fire or spontaneous combustion ;**
- **a surface fire where products of combustion may affect underground workings;**
- **an inrush of gas from disused workings;**
- **an inrush of water or material that flows when wet;**
- **an incident involving persons trapped by equipment, machinery or fall of ground; and**
- **an uncontrolled outburst of gas or mineral.**

The plan must address the risks which could arise to personnel should any of these events occur, the measures necessary to enable persons to escape to safety and protect them whilst doing so and the provisions in place to rescue them if they are unable to escape without assistance.

'...internal mock exercises will not necessarily identify potential problems in co-ordinating responses from neighbouring mines under different owners.'

Testing the Emergency Plan

Only by effective commissioning, regular testing and periodic updating will the emergency plan be effective and robust. Desk-top 'mock emergencies' will provide information on how the plan may operate in theory, but it is only by full, unannounced activation of the plan that the real picture will emerge. This presents problems and challenges in a privatised mining industry since such an exercise could involve loss of production, additional wages for part-time rescue workers called out from home and from other mines and the attendance of the Mines Rescue Service staff and permanent corps. It is prudent to carry out such a severe test periodically since internal mock exercises will not necessarily identify potential problems in co-ordinating responses from neighbouring mines under different owners.

Incident Control

All decisions and instructions conveyed to and from underground staff that affect the rescue operation should be channelled through one person who is identified as the 'incident controller'. It is desirable that emergency co-ordination and direct incident control functions are separated. The mine manager must take executive control of the event and his time cannot usually be split between these two vital roles. Once the emergency plan is put into operation, many distinct and separate duties will fall upon the manager and his substitute, so it is vital that a competent incident control post is established as part of the emergency plan. This may not be necessary in a short operation lasting only a few hours.

Appropriate staff should be identified and trained. A suitable location equipped with internal and external communication systems should be ready for use as an incident control room; it would not normally be in the manager's office, but should be nearby.

The post of incident controller is an entirely separate and more senior post than the 'control-room attendant' and should be filled by someone of a relatively senior management grade. In most emergencies the control-room attendant will play a vital role in initiating the emergency response. Where possible, he should be assisted and ultimately relieved of this front-line responsibility by a more senior post-holder who is the 'incident controller'. The 'control-room attendant' will still have to fulfil his normal role and, like the manager, cannot do both jobs indefinitely. The post of incident controller is usually filled only in an emergency situation.

Evacuation Zones

Managers of large mines having distinct districts or ventilation systems may find it useful to split the mine into emergency response zones. This will simplify the approach to be adopted whilst concentrating resources where they are needed. The major static fire hazards, such as belt conveyors and electrical installations, should be identified and an escape strategy planned with this in mind.

The speed at which mine airways would become contaminated can be predicted using mine roadway ventilation, time-lapse plans. The plans are marked off in increments of one minute, based upon roadway air-speed. The system can be a significant aid to quick assessment of the situation and correct selection of a route for safe evacuation. In mines employing room and pillar working, where ventilation currents can be sluggish, vehicle or compressor fires can result in heavy local air contamination. Time-lapse plans can assist in identifying the rate of smoke dispersal and locating sections of the mine where contaminated air can be temporarily 'dumped' by altering air doors, thus increasing the time available for people to escape.

Large non-coal mines can present specific problems of locating underground staff in an emergency because of the extensive nature of the workings and dependence on motor transport. The provision of radios for each group of people underground and for every person working or travelling alone would be of significant benefit. Where this is not reasonably practicable, general audible or visual alarms must be employed. In some instances, the introduction of strong odours (such as eucalyptus oil) into the compressed-air system will be the signal for underground staff to initiate an emergency evacuation plan.

SELECTION OF SELF-RESCUERS

It is the mine owner's duty (Regulation 10) to provide suitable self-rescuers and, where necessary, safe havens or facilities for the exchange or recharge of self-rescuers. The selection of self-rescuers and location of safe havens cannot be considered in isolation and must relate, through assessment of risk, to the following factors:

- **The mine layout.**
- **The principal risk, eg fire, explosion or outburst.**

- **The length, gradient and ventilation of development headings or tunnels.**
- **The length and gradient of long advance or retreat coal production faces.**
- **The environmental conditions, particularly in regard of hot and humid conditions.**
- **The dependence on, and location of, transport systems.**
- **In respect of storage mines, the material being stored.**

Evaluation of mining accidents indicates that many miners who survived an initial fire or explosion but died in the aftermath would have remained alive if they had been equipped with appropriate self-rescuers to permit them to evacuate to the nearest unaffected ventilation current or safe haven. Approved Codes of Practice (ACOP) 48 and 49 deal with the two main types of self-rescuers available.

Filter Self-Rescuer

The filter self-rescuer (FSR) currently in use in British coal mines is designed to provide the wearer with protection for 90 mins against carbon monoxide in a H_2O saturated atmosphere. Its principal advantage over a self-contained self-rescuer (SCSR) is that it is relatively light and compact and provides a long period of wearer protection. It is of such dimensions and mass as to be readily carried at all times, which is considered to be an essential feature of any primary self-rescue system. In the panic that can follow an incident or if a pressure blast or smoke causes loss of vision those affected may be unable to locate their self-rescuer if it is elsewhere than on their person. Where self-rescuers have been provided deaths can occur as the result of[5]:

- **failure to locate the self-rescuer after an incident;**
- **failure to put the self-rescuer on properly or to continue to wear it; and**
- **failure of the self-rescuer to provide protection until fresh air is reached.**

A FSR will provide protection against many toxic fumes given off in a fire in addition to carbon monoxide, but oxygen must always be present at a sufficient level to sustain life. If the wearer does not exert himself physically, protection will continue for some time beyond the nominal 90 min period. The latest MSA290 model in common use in British coal mines has benefited from redesign following the Cardowan explosion in 1982; it is now easier for men who have sustained burns to their fingers to remove from the case.

FSRs have provided many years of reliable service to the British mining industry and are well understood and trusted by the workforce. FSRs are suitable for general use where the risk of explosion or gas outburst is low, the high ventilation quantities possible in modern mines can maintain oxygen levels, and effective environmental monitoring systems are in use and regularly tested. Environment 'norms' will be known and variations will activate pre-set warning and alarm messages. The importance of adequate self-rescuer maintenance, however, cannot be overemphasised and it should be noted that the effective wearing period of a FSR is considerably reduced if the hopcalite oxidising compound has degraded.

At current technology levels a FSR can normally be worn for up to five times as long as an oxygen self-rescuer of a similar mass and whereas the oxygen runs out rapidly from the latter at the end of its wearing period, a FSR will offer a more gradual reduction in protective capacity.

Whilst it is acknowledged that the FSR can provide protection against a wide range of toxic gases generated as products of combustion, these are not necessarily specified in the performance tests and in certain circumstances, depending upon the constituent pollutants, inhalation resistance may become uncomfortable. If oxygen levels are significantly reduced following an explosion, outburst or serious fire, the wearer of a FSR could be in serious trouble. Normal air contains 20.93% oxygen. The statutory minimum is set under section 55 of The Mines and Quarries Act 1954 at 19%. At about 16% a flame safety lamp will extinguish and at 13% work becomes difficult, breathing becomes rapid and a headache will be experienced. Below 11%, exertion will lead to unconsciousness[6]. During oxygen starvation, decision-making capability will be impaired and people may become confused and incapable of making rational judgements and choices.

FSRs currently in use are less comfortable to wear than a chemical oxygen self rescuer (COSR) on account of its higher breathing resistance and the fact that the entire mass of the self-rescuer is worn on the face. New designs attempt to address these issues. Wearers of FSRs must walk at a moderate pace, otherwise they may experience serious physical distress. The chemical conversion agent in the FSR will heat up when exposed to high levels of carbon monoxide and if the entire apparatus is worn on the face, this will require strict discipline on the part of the wearer to maintain the rescuer in the mouth, even when it is uncomfortable and warm. It is therefore essential that wearers are given the opportunity to experience 'hot inhalation air' during training. Special training models should be provided for this purpose.

The increased breathing effort required when a FSR is worn is likely to reduce physical performance, particularly in hot and humid conditions.The increased workload on the heart may become significant at effective temperatures exceeding 29°C[7]. The ultimate distance walked will be a function of the physiology of the wearer, not only the self-rescuer. Safe wearing times could, therefore, be significantly less than the actual rated duration afforded by the equipment's ability to protect against products of combustion.

'FSRs have provided many years of reliable service to the British mining industry and are well understood and trusted by the workforce.'

Oxygen Self-Rescuer

SCSRs are of two essential types—compressed oxygen sets and chemical oxygen sets. At present, only COSRs have undergone suitability trials by the Health and Safety Executive (HSE) for use in mines [ACOP 46(b)(ii)]. Those considered appropriate for use in mines are either approved in pursuance of the Control of Substances Hazardous to Health Regulations 1994 (COSHH) and have been assessed in trials carried out under HSE supervision or are 'CE' marked.

The major benefit of a SCSR over a FSR is that it functions independently of the outside atmosphere. This can be a considerable psychological boost to the wearer. COSRs appear to restrict breathing less than a FSR except at the beginning and end of the wearing period. Near the end of the COSR wearing life the temperature of the inspired air increases, but during mine trials wearers were generally impressed by their relative comfort. COSRs may, therefore, prove more acceptable than FSRs when heat and humidity are an issue and where CO is present. However, COSRs are generally heavier and physically larger than a comparable FSR.

The major drawback of a COSR is the relatively short wearing time available from units small enough to be kept on the person. In some cases, units having a rated 30 mins-wearing time may only last 20 mins, which can be reduced even further if the wearer is large or the workload is very heavy. This may be because the wearer time is stated at low oxygen demand, possibly as low as 30 l/min. This must be assessed carefully when comparing performance data for different COSRs. It is essential to establish what oxygen consumption rate is being used to define the wearing time. As a guide, it can be assumed that a miner of average size and fitness will require an oxygen supply of between 40 l/min and 45 l/min when walking in normal underground conditions and temperatures whilst wearing a COSR. Sets with a duration of 90 mins are available, but these are too large to be carried constantly by people who are working.

The 'nominal' European standard is based upon a self-rescuer fitted to test equipment 'breathing' at a fixed rate of 35 l/min. When selecting a COSR a mine manager should satisfy himself as to the 'real life' wearing time of the equipment through trials by his own staff in his own mine conditions.

'When selecting a COSR a mine manager should satisfy himself as to the "real life" wearing time of the equipment through trials by his own staff in his own mine conditions.'

It is beneficial that a COSR should be equipped with an 'oxygen starter' and not require the wearer to take several inhalations of potentially contaminated air before putting on the nose clips. This is especially important in situations where sudden contamination of the atmosphere is considered a risk. The implications of having to swap a depleted COSR for a fresh unit in contaminated air are also clear. However, where possible any change-over should be carried out at a suitable safe haven or change-over station.

Where a risk assessment has identified the likelihood of an oxygen-deficient or toxic atmosphere and resulted in the selection of a COSR, a safe haven or facility for exchanging the short-duration personal COSR to a long-duration set will be required close to the workplace unless it is near fresh air.

Training will play a vital role in ensuring that those required to use a COSR do so correctly. Training models are available, but there is one very significant feature of a COSR which can only be experienced by actual wearing. Where no self-starter is provided, the oxygen production of the set will be generated by the warm, moist exhaled breath of the wearer. It follows that a slight delay may be experienced by the wearer between donning the rescuer and an ample supply of oxygen being delivered.

Where an oxygen starter system is provided, this effect is delayed and may be experienced after two to three minutes of wearing when the oxygen starter runs out and the chemical oxygen supply initiates. The oxygen bag will then fully inflate and the wearer will have oxygen on demand. It is vitally important that the wearer is aware of this phenomenon and does not panic; the comparison with the 'hot air' experience for FSRs is clear. Every potential wearer of a COSR should be prepared for this and, ideally, given the opportunity to wear an operational model at least once during training.

SELECTION OF SELF-CONTAINED ESCAPE BREATHING APPARATUS

In addition to Regulation 10, self-contained escape breathing apparatus is referred to in a number of sections of the 1995 Regulations. Careful selection of the type, duration and place of storage is essential and should be based upon the intended use.

Appendix 2, 3(o): Additional Self-Contained Self-Rescuers: 'Escape Apparatus' Immediately Available at the Mines Rescue Station

These could be the AGA escape apparatus replacement and therefore be of the longer-duration, 90-min type COSR, which compare favourably in terms of wearing duration with the SEFA (Selected Elevated Flow Apparatus), breathing apparatus, which would be worn by the rescue team.

Appendix 2, 1(d): Five Self-Contained Self-Rescuers to be Carried on the Vehicle

Self-contained, ie oxygen, self-rescuers should be provided for the personal protection of the Mines Rescue team members and be worn on the person by the rescue team in case their self-contained breathing apparatus fails. To be worn in addition to a breathing apparatus (BA), the self-rescuer has to be lightweight and therefore will inevitably have a shorter duration, nominally at least 30 mins but preferably 60 mins. The latter could cope with the worst situation and maximum distance travelled by the rescue team, should a fault occur on a BA after it had been worn for one hour (SEFA wearing time is 2 hrs with a 20% reserve in low mode). For obvious reasons, the COSR in this application should be equipped with an oxygen starter system.

Regulation 6

Every mine of a type referred to in Regulation 3(2), that is, mines of coal and other mines having the potential for significant levels of firedamp or an irrespirable atmosphere, must keep 'at the mine' six sets of self-contained self-rescuers, or one per person working underground, whichever is the fewer. In large mines these units should be maintained at a suitable location on the mine surface as an emergency back-up and 'pool' of spare escape apparatus. At small mines where a significant risk of oxygen deficiency is identified, probably due to blackdamp, each miner should be provided with a SCSR and this would satisfy the requirement.

To replace the smoke tube apparatus, which was a 'rescue apparatus' designed to be worn by a competent person, not necessarily a member of the rescue service, and for use over relatively short distances, at least one of the sets mentioned in regulation 6 should be a purpose-designed 'working set'. This equipment could be stored on the mine surface, in the rescue room. These differ from 'escape' sets in that they have an audible alarm to indicate the remaining safe period of wear and may have a face mask, which can be of significant benefit in enabling the wearer to communicate and can improve vision and comfort in a smoke-filled atmosphere. Modem compressed-air, air-line type apparatus is also available which could be considered as a direct replacement for the old tube breathing apparatus. The most likely use and therefore location for such purpose-built 'rescue' equipment would be on the surface of a mine.

At present, surface workers are not equipped with any form of self-rescuer. There are many locations on a mine surface where personnel could become trapped by an irrespirable atmosphere caused by fire—coal preparation plants, winding engine houses, compressor houses, methane drainage plants, to name but a few. Lightweight filter smoke hoods would provide an adequate period of protection in most circumstances, with the added benefit of protecting the face and eyes from heat and smoke whilst facilitating speech communication since no mouthpiece is necessary.

DESIGN AND SITING OF SAFE HAVENS

Whilst widely applied abroad, the provision of safe havens is a relatively new concept in British mines that has never before been addressed by regulation. There have, however, been parallels of a sort. Air supply lines have been installed in seams where there was a history of methane outburst. These normally took the form of filtered compressed-air supplies, placed at intervals in roadways and faces. Access was gained by pulling out a tube and directing the air into the worker's helmet, out of which the worker then breathed.

The provision of safe havens is covered in Approved Codes of Practice 51 to 54 of the 95 Regulations. Such a place is identified as having an independent air supply to maintain the atmosphere at a positive pressure (greater than the surrounding atmosphere), such that persons may wait in safety until rescue arrives. It should be noted that 'independent' refers to the independence of the atmosphere of the safe haven in relation to that in the roadway and does not necessarily mean 'dedicated', ie it would not normally be considered necessary to install a dedicated airline back to the surface compressor if such a supply were already installed in the roadway. The compressed air should be filtered and monitored for carbon monoxide (which can be produced by faulty compressors). Some mines may depend on underground compressors for their compressed-air source and to support safe havens the electrical power to these units would have to be assured by a dedicated supply, otherwise a separate, surface-based compressed-air system may indeed be required. Most underground compressors are, for reasons of cooling, located in main intakes, so it should be feasible to maintain power in an emergency situation.

In certain locations around the world where shallow mining is carried out, surface boreholes provide an independent air supply and a means of supplying fresh drinking water and communication, but other than at a few shallow non-coal mines, there are few applications for this in the UK. Modern oilwell drilling techniques are extremely accurate and may eventually be able to target specific areas in a deep mine.

Design of Safe Havens

The design of a safe haven depends on the proposed use; there are two main types:

(i) **Sealed units with airlocks and a positive air supply equipped for communication and suitable environmental monitoring where people can wait without wearing self-rescuers. Owing to its size, such an installation would have to be located in a main roadway at some central location appropriate to the district. This type of safe haven could serve as a focal point for persons assembling from a wide area and would be appropriate for large non-coal mines or the larger coal mines, where excavation on a sufficient scale could be carried out and where mine workings were extensive and distant from the surface shafts or drifts.**

(ii) **Semi-sealed installations, such as canopies** (Figures 4.1 and 4.2) **or pressurised tent-type refuges** (Figures 5.1, 5.2 and 5.3), **having an air supply that induces positive pressure where people can change self-rescuers before continuing outbye or can wait to be rescued whilst wearing filter or self-contained self-rescuers. These are compact designs which can be deployed in under 15 secs, can be positioned at suitable locations and would be especially relevant in warm and humid conditions. A signalling or communication system is vital to identify and locate persons taking refuge.**

It is recommended that safe havens are equipped with vital survival equipment and material such as:

- **environmental monitoring equipment;**
- **survival food and water supplies;**
- **means of communication;**
- **plans showing escape routes to fresh air or other safe havens;**
- **exchange long-duration self-contained escape apparatus; and**
- **basic first-aid equipment.**

Use of Safe Havens and Self-Rescuers in Hot and Humid Conditions or Smoke

Advances in technology will inevitably lead to ever longer self-rescuer capacity. FSRs with a nominal capacity of more than 4 hrs are already on the market and progress in the design of longer-duration, compact SCSRs, using compressed gas and chemical systems is continuous. However, when wearers are subject to high levels of stress, such as are experienced when attempting to escape following an underground fire or explosion, the principal limiting factor of long-duration breathing sets will often not be the equipment but the wearer. Instances have occurred when workers have removed their self-rescuers, even in irrespirable atmospheres, because they could no longer stand to wear them.

'...the principal limiting factor of long-duration breathing sets will often not be the equipment but the wearer.'

Any benefits of the COSR over the FSR in terms of physiological performance in hot and humid conditions will become less significant as environmental conditions become more severe. As a guide to how extreme environmental conditions may affect self-rescuer wearers, reference should be made to the Mines Rescue Service safe wearing time charts[8,9] for breathing apparatus in hot and humid conditions (**Table 1**). Experience with breathing apparatus suggests that the relative physical performance criteria, for various types of apparatus, converge as environmental conditions become more acute (**Figure 6**). The ability of the equipment becomes secondary to limitations imposed by the physiology of the wearer. Similar observations were made during self-rescuer wearer trials.

This does not imply that there is no benefit in having a long-duration self-rescuer available. Quite the reverse. Persons resting or taking refuge in a safe haven whilst wearing self-rescuers will be able to wear them for much longer periods because they will not be subjected to a heavy workload. This is termed the 'entrapment procedure' and is a well recognised method of extending the wearing time of breathing apparatus or self-rescuers.

In large mines, where workers escaping may have to walk long distances, in hot and humid conditions, possibly in smoke, it is considered unwise to plan an escape policy based solely upon the use of self-rescuers. Research and wearer trials indicate that in normal walking conditions and in a relatively comfortable environment the following operational parameters exist:

- **A person equipped with a nominal 90 min COSR will have approximately 70 mins' wearing time during which he could cover 3 000 m to 4 000 m. This does not take into account any disorientation, fatigue or stress and assumes unrestricted vision.**
- **Wearers of nominal 60 min COSRs could display significant distress after 40 mins to 45 mins owing to oxygen depletion and may travel up to 2 000 m, in clear vision conditions.**
- **A 30 min nominal duration COSR may provide as little as 17 mins' wearing time and could limit travelling to between 500 m and 1 000 m.**

Repeated wearing trials in various mine conditions indicate that the optimum safe walking speed for people wearing self-rescuers is 50 m/min or 3 km/h.

'Modern legislation is goal setting, in the belief that industry will be responsible, largely self-regulating and capable of recognising risk to employees.'

The likelihood of poor visibility and of high heat and humidity means that realistic estimates of self-rescuer operational limits, in terms of time and distance travelled, must be lower than those above. In 'saturated' hot and humid conditions in excess of 30°C safe wearing times should be considered to be less than 45 mins, reducing to under 30 mins for saturated atmospheres at temperatures over 32°C, regardless of the design or duration of the self-rescuer. It can therefore be asserted that in large, warm and humid mines, coal or non-coal, regardless of which type of self-rescuer is provided, safe havens will be required close to the place of work and strategically placed at intervals in the mine in order to permit men to rest whilst escaping or, where appropriate, take refuge until rescue teams have brought the hazardous environment under control.

In long-distance, single-entry, auxiliary ventilated developments there is a risk of an irrespirable atmosphere occurring through oxygen reduction and destruction of the ventilation duct in a fire. The presence of free-steered vehicles increases the risk. The formation of soot caused by burning oil, tyres or conveyor belting may block the filter of a FSR, resulting in a significant increase in breathing resistance. The selection of a COSR for such locations would be appropriate and this, by implication, would require safe havens close to the place of work where short-duration sets could be uprated.

In long-life, warm and humid production longwall coal faces oxygen depletion may be less likely, but due consideration must be given to the mines rescue implications of, especially, the limitations placed on apparatus wearing times in hot and humid conditions. During the 1992 Stillingfleet mine incident, when eight men were trapped for over 15 hrs, temperatures of 32°C wet/35°C dry were experienced; had breathing apparatus been required, the safe wearing times of the SEFA used by the Mines Rescue Service would have been limited to 31 mins. It must be further appreciated that this translates into only 10 mins' walking time each way and 10 mins' working. In limited visibility the distance travelled could be as little as 200 m. Climatic control that can moderate the most extreme conditions for day-to-day operations could not be guaranteed to function in an emergency, when electrical power may be isolated.

There is no evidence to suggest that men attempting to escape whilst wearing self-rescuers in hot and humid conditions could be expected to fare any better than a rescue team attempting to reach them. At Thoresby Colliery, Nottingham, in 1995, during a rescue attempt when men were trapped by an irrespirable atmosphere at the face of a development heading, a Mines Rescue worker collapsed whilst wearing breathing apparatus as a result of the heat and humidity, demonstrating the difficulties which can be experienced. Attempts to improve the performance of Mines Rescue teams in hot and humid conditions by equipping them with 'cool gel vests' and open-circuit breathing apparatus may provide a slight psychological boost, but appear to have little actual physiological benefit owing to the fundamental difficulty of lowering the core body temperature. The biggest improvement appears to be achieved by providing frequent sips of cool water—unfortunately not an option normally available whilst breathing apparatus or self-rescuers are being worn. Safe havens may therefore also have a role to play, not only in escape from the mine, but also in rescue of workers from long, hot and humid mine roadways.

In essence there may be only two choices: either limit the extent of workings, especially in hot and humid mines, or put in place an emergency plan which deals with the situation adequately and recognises the physical limits imposed on anyone required to wear breathing apparatus or self-rescuers in an emergency.

Modern legislation is goal setting, in the belief that industry will be responsible, largely self-regulating and capable of recognising risk to employees. In the UK mining industry the signs are generally encouraging and most employers appear to be proactive in addressing health and safety issues. The new risk assessment-based Escape and Rescue from Mines Regulations 1995 set out a framework to guide and assist in the formation of a comprehensive emergency escape plan and mines rescue facility. A considerable boost to this was the preservation of the Mines Rescue Service as a national body.

In comparison to some modern statutes, the Escape and Rescue from Mines Regulations 1995 are a prescriptive package, but also, and entirely in keeping with the aim of all new regulation, they place considerable responsibility on the employer to evaluate and put in place an appropriate emergency plan. Where legislation permits more flexibility, there also lies greater responsibility. Risk assessment must never be employed as a means of justifying low standards but as a device for evaluating actual risk and targeting resources to achieve the highest possible standards. Mining is a global operation which periodically reminds us of its ever-present hazards. The safety record of the British mining industry is second to none, owing to the constantly evolving attitude to mining safety demonstrated by mine owners, managers and the workforce. To maintain and improve upon this high standard, it is necessary to build on past experience and embrace new concepts where these can be justified.

CONCLUSIONS

- **Provision of an emergency communication system in single-egress workings should be considered where reasonably practicable. Where this cannot be provided, additional protection of the existing telephone cable should be made a priority.**

- Emergency provisions of food and drinking water should be made available where there is a risk of entrapment.
- Emergency tunnelling equipment should be held at suitable locations and 'dig out' rescue teams arranged, especially for small mines, where volunteers would need to be gathered from a number of mines. Call-out lists should be available to the Mines Rescue Service, which would co-ordinate such a response.
- Careful consideration is necessary when selecting self-rescuers. This cannot be done in isolation from other mine factors and must be integrated into an overall emergency plan.
- Tests carried out on various types of self-rescuers in the UK confirm that their performance is not only site-specific but also varies between wearers, depending on their fitness, age and, particularly, physical mass. There is a maxim in the Mines Rescue Service that 'a rescue team can only travel as fast as the slowest team member'. This would also hold true for groups of men escaping from a mine whilst wearing self-rescuers.
- Following a considerable number of wearer trials of self-rescuers, it is considered that a moderate pace of 3 km/h (50 m/min) is the optimum escape speed upon which to plan evacuations of persons wearing self-rescuers. This does not take account of loss of visibility.
- To provide immediate protection in an emergency (such as a gas ignition, explosion or outburst, when visibility will be reduced to near-zero by dust) the self-rescuer must always be worn on the person. Whilst this limits the size of the unit which can be comfortably carried for long periods, it guarantees that the self-rescuer is where it is needed in an emergency—with the wearer.
- Self-rescuer manufacturers should take comfort into consideration when designing their equipment to ensure not only that the casing is ergonomically correct in terms of being easily opened, even by burned hands, but also as comfortable as possible to wear continuously on the miner's belt (eg body-hugging shape).
- Purchasers of COSRs may have to circumvent the problem of obtaining a self-rescuer of long duration but with relatively small mass by adopting a policy of safe havens, where lightweight, medium-duration SCSRs can be exchanged in a place of safety for longer-duration escape sets.
- Whilst the founding principle of any emergency escape plan must always be to evacuate the mine with the minimum complication or delay, for reasons put forward in this paper this may not always be possible. No one would embark upon an ocean voyage in a large ship equipped with only life-jackets; sufficient lifeboats would also be required. Similarly, establishing an effective emergency survival strategy with the use of safe havens could enhance the chances of escape from large, warm mines, whether the self-rescuer be of filter or self-contained type.

ACKNOWLEDGMENTS

The author would like to thank Mr Brian Langdon, HM Chief Inspector of Mines, for his guidance and permission to present this paper and Mr Howard Evans, HM Principal District Inspector of Mines, for his advice and encouragement. Any views expressed are those of the author and not necessarily those of the Health and Safety Executive.

DISCUSSION

Professor A W Davies (Cardiff): I congratulate Mr Forster on his timely paper, which makes us more familiar with the new rescue regulations. I would like to make some comparisons with the self-rescue position in South Africa, where over half a million people are employed in a variety of mineral extraction operations, including the coal mining industry, which now produces some 200 Mtpa and exports over a quarter of this tonnage.

Following the disastrous fire at the Kinross gold mine, when 177 lives were lost in 1986, self-rescuers were required to be

Figure 1 Partial access available

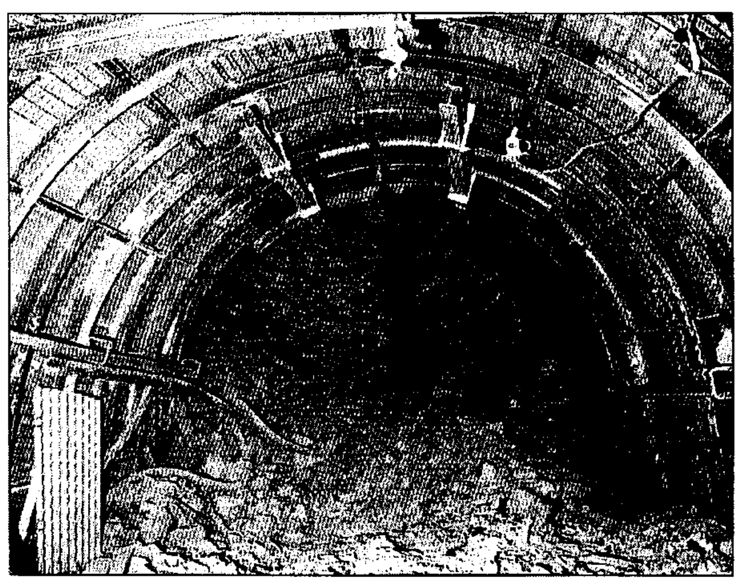

Figure 2 Compact closure

provided for persons going underground. FSRs were not considered suitable and SCSRs were the only ones approved by the Government Mining Engineer. Rescue bays (or safe havens, as they were described by Mr Forster) were also required by regulations.

In a disaster which I was asked by the Government agencies to investigate in 1993, 53 persons were killed in two underground districts, both equipped with continuous miners and associated equipment. In the district where the explosion originated the blast effects and violence were so severe that the SCSRs which everyone wore on their belts were to no avail. In the other district, where about half the victims were employed, blast effects were not severe, but products of the explosion invaded that district rapidly, producing a thick black cloud of particulates and carbon monoxide, with nil visibility. All the persons on this district, who had received training in the use of self-rescuers, successfully donned them, but because of nil visibility and disorientation many remained huddled together and many exhausted the supply of oxygen in their self-rescuers, lasting about 25 mins, before they died. Others did start to make their way outbye to the rescue bay. Disorientation caused some who had started in the right direction to turn and go back the way they had come. Sadly, when I came to examine the rescue bay, I found that there was neither the provision of additional oxygen or air, or longer-duration rescue sets, nor a borehole and air pump from the surface (which are often provided in these mines, which are only about 100 m deep). Anyone who could have reached the rescue bay would have perished there.

The issue of disorientation has been looked at since this explosion, and I was recently shown a system installed in a continuous miner district underground, using small (about 6 mm diameter) hemp ropes, fitted with small plastic cones along their length, so that someone using the ropes as a guide is given a direction by them. Rescue bays have been designed —now called Mobile Rescue Stations (MARS)—and are being marketed. They can accommodate 18 persons and give life support for 13 hrs using two independent systems—18 x 50 litre cylinders, and 18 long-life, approved self-rescuers of 5 to 6 hr capacity. MARS can be towed in the district to keep up with the fast moving equipment, but are seen as complementary to existing refuge bays. They are fitted with flashing beacons and alarm sirens which operate independently of the power supply. (See page 37 of the January/February 1997 issue of the *Journal of the South African Institute of Mining and Metallurgy*).

A more recent incident in a coal mine in South Africa involved a continuous miner cutting through a pillar to intersect waterlogged old workings. About 40 M gallons of water entered the active workings. The continuous miner driver was swept away to his death, but the other persons in the district were saved because the gradients in large areas of workings were favourable. They walked out on the conveyor belts. Police divers were used to try to locate the missing continuous miner driver. I have always opposed the use of non-mining trained divers in these situations. The law requires persons employed underground to be trained for that purpose. I recall the Lofthouse Inrush, where the need for rescue teams to enter waterlogged areas arose. Following that experience, swimming pools were constructed at some Central Rescue Stations to provide a training environment for rescue men who may have to deal with waterlogged situations. Under the new arrangements, do rescue men still have the benefit of this specialised training?

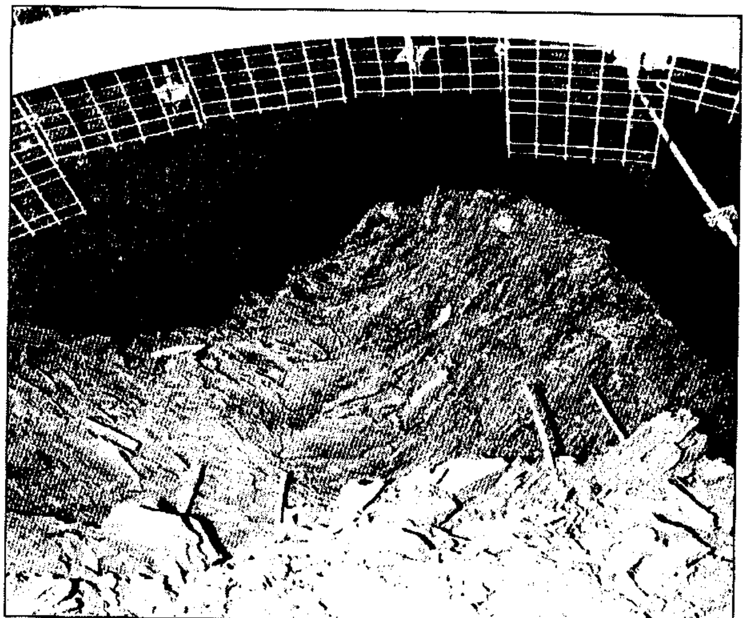

Figure 3 **Collapse of an arch and rockbolt 'mixed' support system**

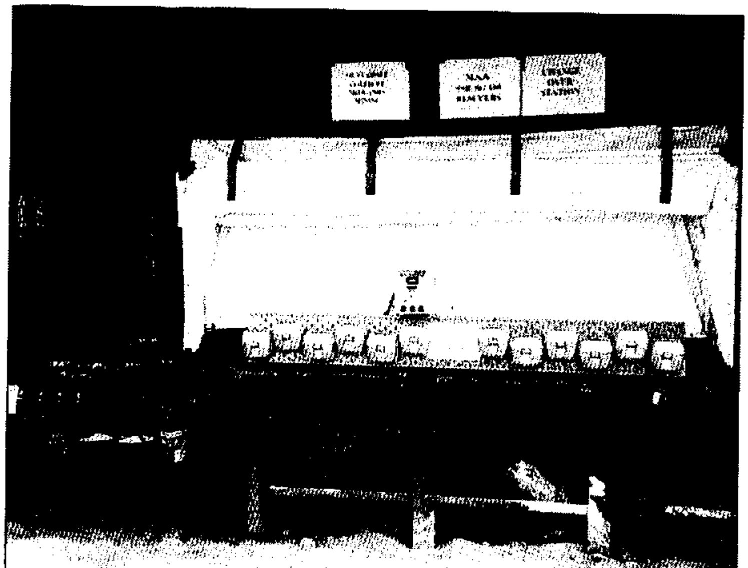

Figure 4.1 **Canopy in stored position**

Author: Thank you for your most informative contribution. I will try to take the points you raise in order.

a) The issue of whether a FSR or a SCSR should be selected requires careful consideration. In my paper I have attempted to direct readers towards the issues I consider relevant to that selection. In relation to the apparent unilateral choice of SCSRs by the South African Government, I am obviously unable to make a definitive comment, except to say that I believe FSRs may still have a valuable role to play in the appropriate situation and selection of the type should be site-specific, based upon the assessment of the risk.

It appears to me that if that risk assessment identifies the major hazard as explosion or outburst, persons risk losing their life in the afterdamp or oxygen-deficient atmosphere which follows, so the only choice is SCSRs. In Great Britain, mainly as a result of advances in high-efficiency ventilation systems and the application of environmental monitoring, the principal hazard identified by mine owners appears to be fire, not explosion. In those cases a FSR would appear to be acceptable. In my paper I have attempted to identify several exceptions to this broad classification.

b) Safe havens are a relatively new concept in Great Britain and where these may be required, mines are in the process of evolving appropriate designs. Whichever design is selected, I cannot conceive of a situation where a mine manager would permit that place of refuge to fall below the agreed specification.

c) The development of navigational aids for use after an underground fire or explosion is currently the subject of some research. If I could comment on the safety line to which you refer, there may be a problem in the logic of this equipment. As I understand it, people using this rope/cone safety line would feel with their hands along the line. When their hand slid over the cones (ie the pointed end), they would be travelling towards fresh air and safety. When their hand came against a resistance (ie the base of the cone) they would be travelling in the wrong direction. The reverse logic in this situation is that the cones, which can also be construed as 'arrows', therefore point towards the hazard, not away from it. This may be something that drilled fire-fighters or rescue workers could be trained to accept, but traumatised workers escaping a fire or explosion may become confused by it. Another system currently being evaluated comprises flashing red and green lights combined with some form of tone generator. Unfortunately, research has apparently indicated that the colour green does not penetrate dense dust and fumes as effectively as red. The problem of navigation following a fire or explosion has been recognised and several theories are currently being evaluated.

d) In relation to the training of rescue workers for inrush type incidents: swimming pools are no longer maintained at Mines Rescue Stations since these expensive facilities, when required, are readily available elsewhere. All Mines Rescue workers are trained to use their SEFA apparatus 'in water', but not 'under water'. This has been carefully evaluated by the National Advisory Committee on Rescue Work and Rescue Apparatus (NACRWRA) and guidance has been published. One team of specially trained Mines Rescue workers is qualified to Advanced Diver status and could, following consultation with Her Majesty's Inspectorate of Mines, use equipment underground in extreme emergencies. I share your reservations about non-mining personnel becoming involved in underground rescue situations, except in extreme emergencies when their particular skills are required and under close personal supervision of the Mines Rescue Service.

Mr S J Reece (Warrington): Does Mr Forster have any information on the likely products of combustion resulting from a major fire on a large diesel, rubber-tyred vehicle of the type found in several mines. Also, would he comment on the effectiveness of FSRs in the removal of toxic gases from the mine atmosphere in addition to their normal use in combating the effects of carbon monoxide.

Author: I am obviously aware of some of the extremely large mobile diesel plant currently employed at your own and other coal and non-coal mines. A fire on such a machine presents the emergency planner with possibly the most difficult scenario. This would obviously become extremely

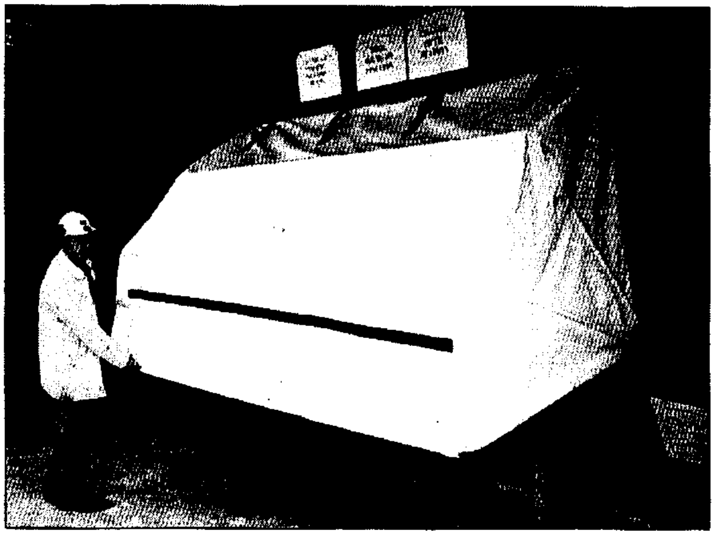

Figure 4.2 **Canopy deployed**

Figure 5.1 **Tent inside steel storage case**

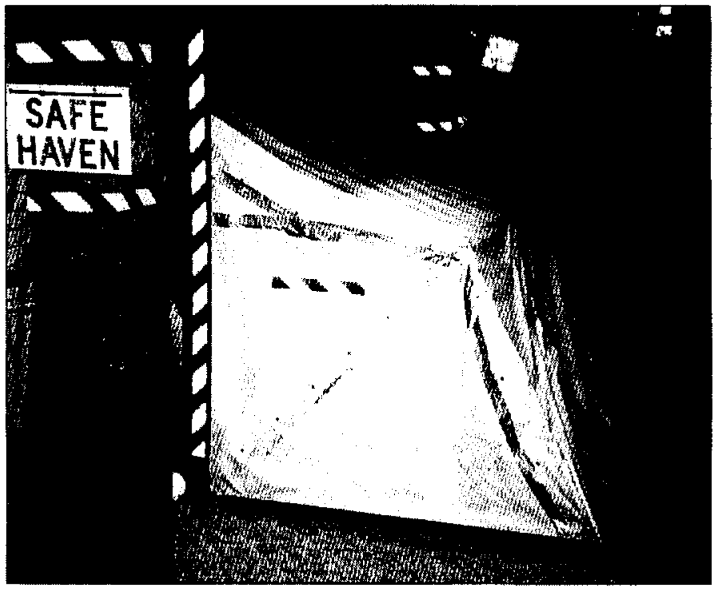

Figure 5.2 **Tent fully deployed**

complicated if that vehicle were also carrying bulk explosives. Because the machine is mobile, the location of the possible event is constantly changing, as is the effect of such a fire on the mine ventilation circuit. Potentially, one of the most hazardous locations for such an event would be in an auxiliary ventilated, single-entry heading. Miners would not only be trapped, but the ventilation ducting would be destroyed. Should the onboard fire-fighting system fail to quench the fire and the electrical wiring loom, seat, hoses and tyres ignite, a cocktail of extremely noxious fumes would be generated in addition to soot, which could clog the filter on a FSR. Thermal effects could cause products of combustion to expand and fill mine roadways, often backing against the imposed ventilation current. In most cases, there will be little option but to let the fire burn itself out. This could take several hours. Some of the gases which could be produced from burning synthetic material, rubber or PVC-based products include chlorine, hydrogen chloride, hydrogen cyanide and phosgene.

The MSA290 FSR currently issued in most British mines is tested to a standard which is that it will provide a minimum of 90 mins' protection in an atmosphere containing up to 1.5% carbon monoxide. Whilst it is likely that it will also provide a level of protection against a range of toxic gases, these are not specified.

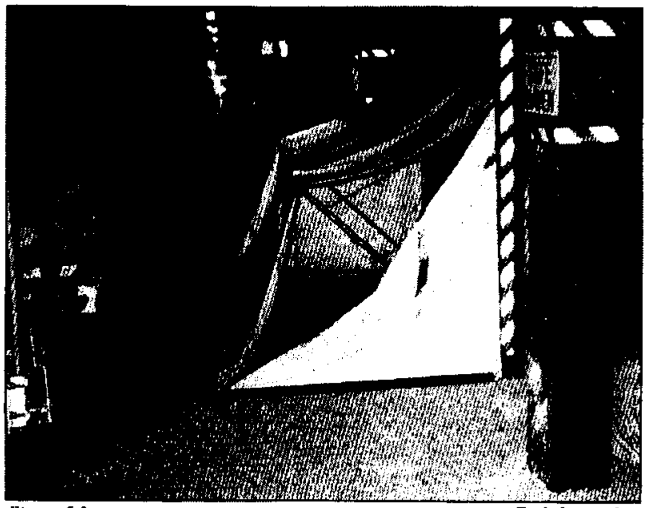

Figure 5.3 **Tent zip opening**

(Fully Saturated Air) Degrees		Minutes Wearing Time		
F	**C°**	**SEFA**	**PROTO**	**AEROLOX**
80	27	-	60	-
82.5	28	63	52	-
85	30	46	44	120
87.5	31	-	38	64
90	32	33	32	42
92.5	34	27	28	31
95	35	-	24	24
97.5	36	22	21	20
100	38	19	19	17

Table I **Combined safewearing time chart**

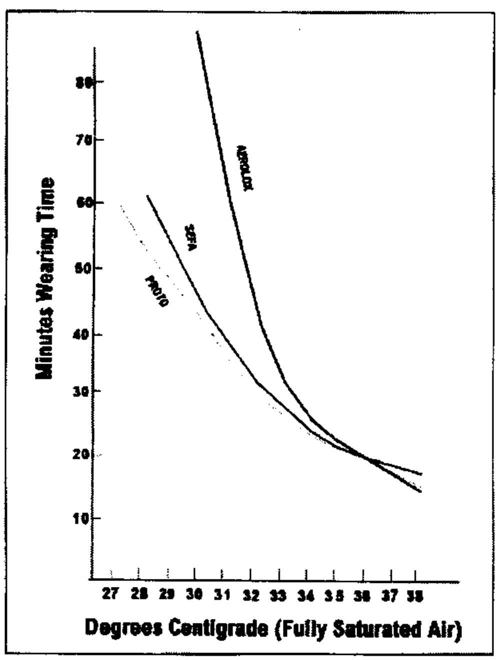

Figure 6 **Apparatus wearing time in hot and humid conditions**

Mr H C Evans (Wirral): I congratulate Mr Forster on his presentation, which addresses a most complex subject which we, in the UK mining industry, must move quickly to support. Certainly, Mr Forster's contribution to the work of the National Technical Committee on Mines Rescue is already acknowledged and this paper will surely complement the work already completed. It provokes further in-depth thinking and perhaps, as its objective, poses more questions than it answers. I would commend it to industry as a significant marker for future action.

VOTE OF THANKS

R A Evans (Cardiff) gave the Vote of Thanks, which was warmly applauded.

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DOCUMENT 23

Use of self-rescuers in hot and humi

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RESEARCH REPORT 180

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Use of self-rescuers in hot and humi

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NG19 9AQ

The concept of self-rescue is premised on the assumption that underground mineworkers have the physical and mental capacities required for self-rescue and in-seam rescue. There is a recognised research 'gap' concerning the practical limitations, and ultimately personal endurance limits, associated with the extended wearing of mining industry respiratory protective devices particularly under high physiological stress conditions. This has important implications for emergency response strategies predicated on seeking to evacuate hot and humid mines. In response to these issues, a programme of research was defined, consisting of:

- a literature review
- an audit of climatic conditions
- laboratory investigations
- a programme of climatic chamber wearing trials.

The wearing trial component of the programme, which involved volunteers being subject to controlled heat stress, was reviewed by and received the approval of HSE's Research Ethics Committee. This work has provided a wider base of fundamental knowledge on physiological response to the wearing of escape respiratory protective devices under hot and humid conditions, and contributes to available guidance on the selection and use of self-rescuers appropriate to prevailing deep mine environments in the UK.

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EXECUTIVE SUMMARY

Background

During events following an underground fire and/or explosion, survival is critically dependent on the effectiveness of respiratory protective systems. Within the UK underground coal industry, the principal personal respiratory protective device is the filter self-rescuer (FSR), which provides a measure of protection against carbon monoxide poisoning. When a risk of oxygen deficiency has been identified, self-contained self-rescuers (SCSRs) should be used, possibly in conjunction with safe havens. SCSR designs are based on either compressed oxygen or chemical oxygen provision, however, all SCSR types used in UK coal mines have a chemical oxygen supply.

In order to escape following a fire, gas outburst or explosion, underground staff are trained to put on their self-rescuers and wear them until they have reached a place of safety or are instructed that it is safe to remove the device. The specific evacuation difficulties posed by deep and laterally extended coal mine workings include hot and humid environments, difficult travelling conditions, and the possible need for extended wearing durations to be endured before reaching safety. The general trend in mines is towards warmer working districts where effective temperatures above 30°C are not uncommon.

The requirements for effective arrangements for escape and rescue are identified inter alia in Regulations 10, 12 and 13 of the Escape and Rescue from Mines Regulations 1995 and the associated Approved Code of Practice and Guidance [Health and Safety Commission 1995]. ACOP section 75 specifically identifies

> "that to be effective the rescue arrangements must address all the hazards identified in the risk assessment .... except where they are absent or present at minimal risk".

At the present time, mines regulations and guidance relating to acceptable limits for risk of heat stress are, at best, incomplete. Within the United Kingdom mines rescue service, a precautionary approach has been defined over a number of years for assessing hot and humid conditions and for what constitutes a safe wearing period for closed circuit breathing apparatus. A number of international incidents have been identified where otherwise healthy rescue personnel have collapsed from heat strain. Multiple fatalities were recorded in the Polish Niwka-Modrzejów coal mine incident on 24 February 1998, and the US Barrick Miekle mine on 17 October 2002. In each case, prevailing conditions involved high heat and humidity.

Whilst mineworkers generally have a high tolerance of arduous mine conditions, there are many contractors, visitors and possibly management staff who have somewhat lower levels of cardiovascular fitness and may lack heat acclimatisation. In the event of an emergency taking place towards the end of a shift, then it is likely that mineworkers would be in a partially dehydrated state. This situation will be compounded for those who have been undertaking tasks with a high work-rate. In this case, their core body temperature may be close to its maximum for the shift. The acclimatisation response to heat requires frequent exposure and is rapidly lost on leaving the hot area. In an emergency there is no opportunity to reduce physiological heat stress by resting prior to using the respiratory protective device. The requirements to undertake evacuation at a steady, paced rate may be compromised by fear and disorientation. Training can help increase this preparedness and ultimately moderate metabolic rate in an emergency situation.

Some mines have an environment consistently close to 100% air saturation. Any loss of ventilation acutely affects the body's ability to be cooled effectively. Whilst selection of rescue personnel can be undertaken to screen out illness and dehydration, a small but significant fraction of the mine workforce would at any time have increased proneness to experiencing heat strain associated with illness. The filter self-rescuer apparatus, under high carbon monoxide concentrations, substantially increases the inhalation air temperature to the wearer, and most probably the breathing resistance, making breathing uncomfortable and adding to the thermal burden on the body. In an emergency evacuation, staged rests may help the body to thermoregulate and lose body heat. However, the motivation to escape may be such that resting is ignored. Traversing uneven or sloping mine floors, particularly drifts, will be associated with a significantly higher work-rate. Travelling up significant gradients in a return airway may present high physiological stress. The Health and Safety Commission's Guidance document [2001] cites elevated risks situations to include:

- Single entry headings;
- Longwall faces with roadways over one kilometre long;
- Hot and humid roadways;
- Steep roadways.

Heat strain involves a complex interaction of mine environmental conditions (temperature, humidity, radiation, air velocity) metabolic heat production rate and clothing. Individual tolerance to heat can vary widely. The effective heat strain on the body will depend on these conditions. Individual response depends on age, fitness, acclimatisation, hydration, and general health. If heat cannot be lost to the environment, heat build up will occur within the body (heat storage). Mines rescue staff have maximum safe wearing times for SEFA breathing apparatus calculated from empirically derived tables. Body pre-heating associated with walking inbye has been shown to have a significant contributory effect in terms of increase in core temperature of rescue brigadesmen [Hanson and Booth 2000].

Underground clothing is likely to be standard, hot climate workwear (boots, shorts, T-shirts, helmet). However, visitors and management staff may be more likely to wear overalls. Significant clothing, such as a combination of overalls and underwear, can act as a barrier to heat dissipation and reduce the effective body surface available for evaporative cooling. This needs to be taken into account.

Experimental scenarios to simulate escape activities primarily involve walking with varying gradients and floor conditions. In practical circumstances it would be reasonable to assume that the individuals may have eye irritation from smoke and must also make their way out in low visibility conditions. Experimental circumstances cannot however cover the use of irritant smoke. In practice it would also be difficult to rule out the possibility of escaping workers offering assistance to their injured colleagues. Any intervention to partially support or assist injured colleagues could dramatically increase heat burden and individual heat stress.

The physiological wearing limits for breathing apparatus are based on a large body of experimental research, and observations of physiological response, including core body temperature and heart-rate. However, no such physiological limiting criteria are currently applied in the use of mine industry escape self-rescuers. Evacuation planning, and assumptions on distances that can be covered in emergency circumstances, are substantially predicated on manufacturers' escape respiratory protective device test behaviour and durations against specified challenge atmospheres. In this regard, whilst UK standard BS EN 404: 1993 prescribes a detailed test methodology for filter self-rescuers, no information is given on the complex physiological interaction with the wearer in demanding conditions of heat and humidity. In part, this is a reflection of the complexity and heterogeneity of human thermal physiological response. This study has attempted to address these issues and seeks to advance the knowledge base on which coal mine evacuation risk assessments are made. The information is also intended to assist HSE in providing guidance and information on the selection and use of self-rescuers in underground mines.

Research Aims

HSE's responsibility to provide guidance and information on the selection and use of self-rescuers when asked invokes a number of potential questions:

- Do current escape arrangements, based essentially on the use of self-rescuers, adequately account for climatic conditions and travelling distances present in underground coal mines?
- Under what circumstances are manufacturers' claimed wearing durations for both FSR and SCSR self-rescuer types valid, particularly where the wearer is subjected to severe conditions of heat and humidity?
- Do unacclimatised underground personnel, such as contractors, technical representatives, managers and inspectors warrant separate consideration in regard to heat stress risks?
- Does an increasing workforce age profile, together with criteria such as body mass and cardiovascular fitness, also need to be accounted for?

In order to adequately address these issues in the context of this work, a number of experimental objectives were identified:

1. Determine whether acclimatisation and heat stress susceptibility play a significant role in self-rescuer wearing performance.
2. Account for workforce population variation of age and fitness.
3. Determine the relationship between heart-rate, core body temperature, work activity and environmental conditions.
4. Assess the impact of the additional thermal burden arising from an SCSR or FSR operating in a high CO atmosphere.
5. Establish whether a relationship can be defined between effective temperature in mines and a safe wearing time for self-rescuers.

In order to address fully the impacts of acclimatisation and the influence of age and fitness within the underground workforce would require test subjects drawn from the entire mining industry workforce. However, the requirements for a high level of medical assessment data and complete medical history led to the HSE Research Ethics Committee restricting test subjects to mines rescue brigadesmen employed by Mines Rescue Service Ltd. Notwithstanding this limitation, a significant programme of research was implemented to investigate physiological behaviour and safety limits whilst wearing mining escape respiratory protective devices.

Research Tasks

In order to provide an improved understanding of the interactions between the wearing of escape respiratory protective devices and the prevailing thermal environment, an integrated programme of research was proposed, comprising three sections as below. Essentially the research involved:-

- an examination of relevant physiological heat stress literature and underground climate conditions

- undertaking investigations towards developing an improved simulation of hot air breathing effects, and

- carrying out a programme of climatic chamber wearing trials using both filter self-rescuers and chemical self-contained self-rescuers (SCSRs) in conditions of high heat and humidity.

It is noted that the wearing trial component of the programme, which involved mines rescue volunteers being subject to controlled physiological stress, was reviewed by and subsequently received the approval of HSE's Research Ethics Committee before any test was undertaken. The scope of the three principal research tasks was as follows:

Task 1. Literature review and scoping review of industry practice and climate conditions

Various emergency escape strategies were contrasted with reference being made to international practice and developments in self-escape. The general climatic conditions present in deep UK mines and representative seams were reviewed. This was a selective report of the range of conditions associated with hot and humid working environments present underground. The reader is referred to **Section 1** for a review of underground climatic conditions.

Task 2. Simulation of high temperature breathing characteristic of FSR when subject to high levels of carbon monoxide

The research activities within this module primarily involved:

- Investigating hot air simulator configurations based on:
  - (a) heat release from soda-lime or alternative exothermic chemical agents (where heat release is a function of respiration rate/work rate), and
  - (b) intake air preheating based on an air heater-heat exchange unit design.
- Application of the hot air breathing unit(s) in the climatic chamber trials.
- Identifying possible industry options for hot air training.

It was determined that the safe limit for water-saturated hot inspired air is of the order of 50°C. Hot air simulation devices using both of the above approaches were developed and assessed. The development of a respiratory protective device hot inspired air simulation unit is described in **Section 2**.

Task 3. Climatic chamber wearing trials of FSRs and SCSRs under high physiological stress conditions

This was the largest single component of the research programme, involving a pool of 25 mines rescue volunteers, with supervision and medical guidance on experiment design and procedure provided by Business Healthcare Limited. A key issue was whether it was possible to maintain adequate thermoregulation during an underground evacuation in hot and humid conditions, whilst wearing a respiratory protective device for the escape.

A climate-controlled chamber at Selby Mines Rescue Station was utilised to develop a controlled environment of between 27°C and 37°C (100% humidity). A range of test temperatures with fully saturated atmospheres was used. Treadmills were used to develop an appropriate work rate. The hot air training apparatus resulting from Research Task 2 was used in the chamber trial programme. The climatic chamber wearing trials focussed on the deployment of a hot air training model filter self-rescuer, with a lesser number of comparative tests conducted using approved SCSR devices (MSA SSR30).

Risk assessment, experimental design and the prescribed limits for terminating the experiment were critical considerations. Physiological monitoring was employed throughout all trials, which involved continuous real-time monitoring and recording of subject heart rate and core body temperature. An experienced occupational physician supervised subjects throughout the trials. **Section 3** onwards reviews the climatic chamber wearing trials and examination of associated issues.

Trial Approach and Observations

The effects of high inspired air temperature and breathing resistance associated with wearing both SCSRs and FSRs were observed against a range of climatic conditions. The investigation focused on determining the impacts on escape travel speed and distance and self-rescuer duration. The effects of limited visibility following an underground fire or explosion were not considered, but would be understood to greatly exacerbate disorientation, psychological stress and would substantially reduce travelling speed.

The experimental procedure involved subjects walking on a mechanical treadmill, at a self-determined pace, in specific climatic conditions whilst heart rate and core body temperature were observed. Three cases were evaluated:

[A] no self-rescuer
[B] wearing a hot air training FSR model, and
[C] wearing a chemical oxygen SCSR.

The tests were conducted within a range of temperatures of 27°C to 37°C (air fully saturated) with the majority of readings taken at either 29°C or 35°C. Regression analysis techniques were applied to the results to identify any correlation between various climatic parameters and subject physiological response indicators.

The trial procedure involved two phases:

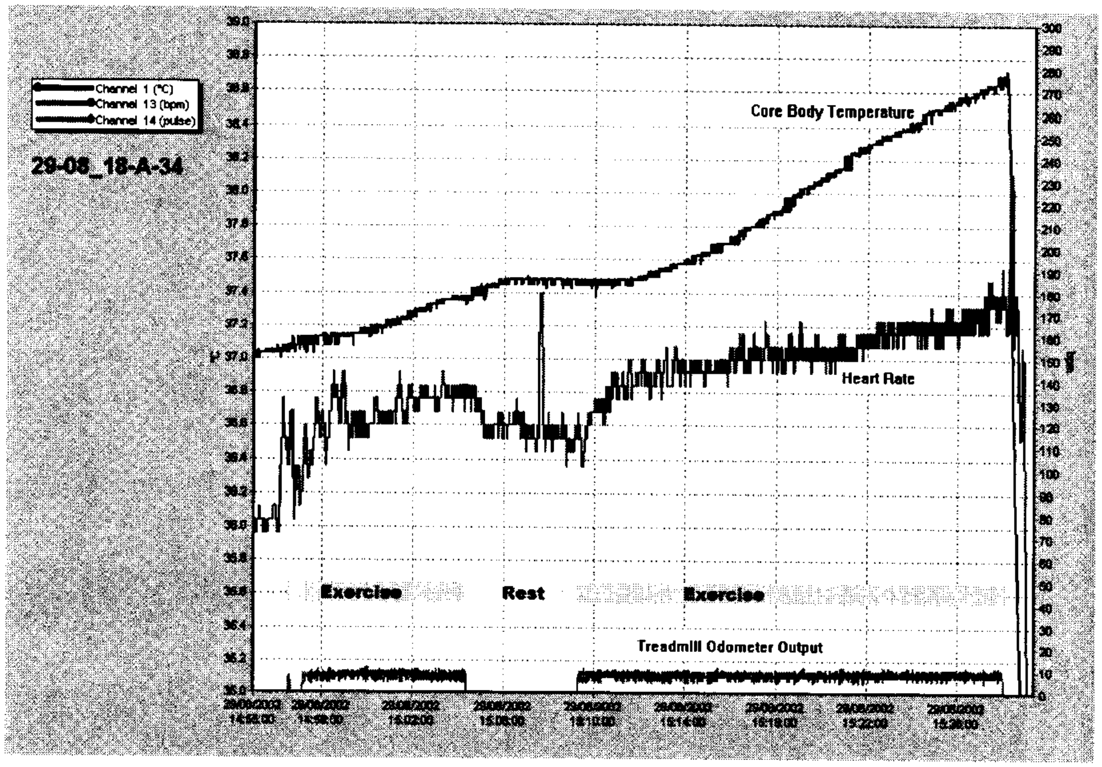
- A warm-up phase, followed by a short rest.
- A second phase where a self-rescuer was worn until the subject was withdrawn.

In the baseline test [A], the subject continued into the second phase without a self-rescuer. The withdrawal criteria were set as follows:

- End of protocol reached
- Exceedence of core body temperature limit (38.5°C)
- Exceedence of age-adjusted maximum heart rate
- SCSR run out, or
- Physician's assessment.

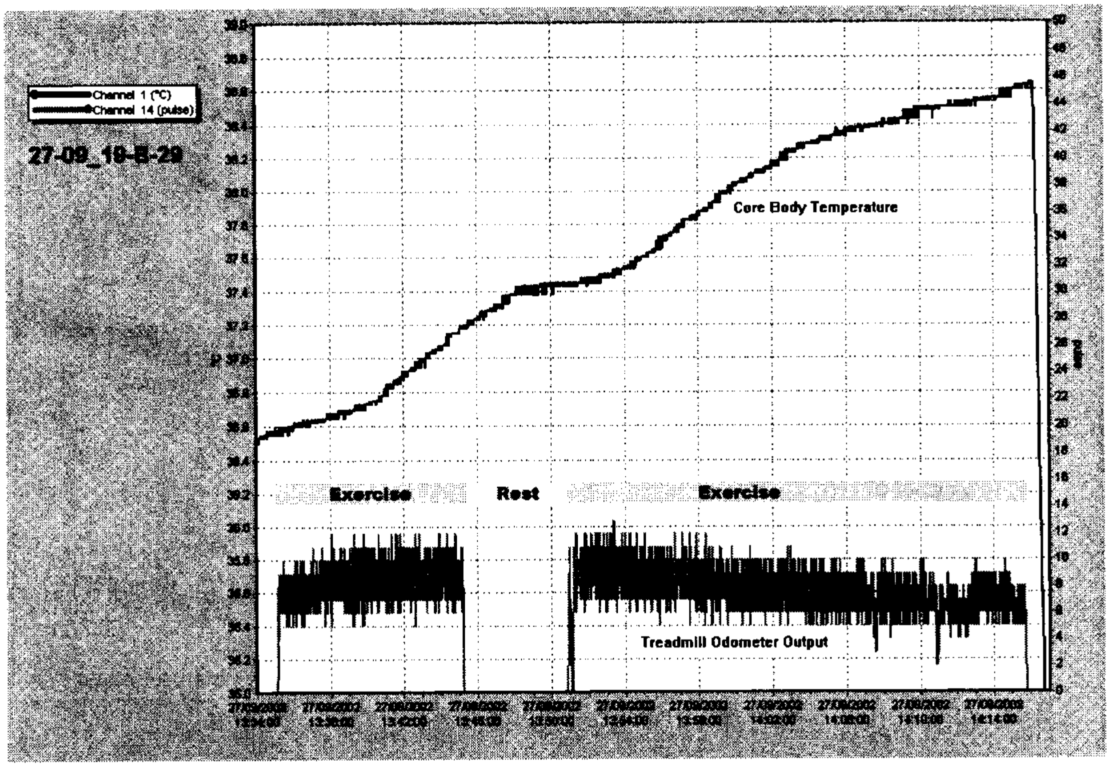
A general observation can be made for all subjects at the prevailing test conditions of heat and humidity. After a brief period of warm-up, all subjects exhibited a progressive increase in core body temperature whilst exercising. The characteristic of the core body temperature rise was influenced by a number of factors including work rate (energy expenditure during exercise), the individual's physiology, and the prevailing climatic stress. Other than a limited number of comparative tests undertaken with overalls, all subjects were lightly clothed (T-shirt and shorts).

It is illustrative to examine the typical physiological response of a subject, in this case undertaken at 34°C BET (air fully saturated). The graph overleaf indicates readings for core body temperature, heart rate and odometer activity from the treadmill. It can be observed that the subject at rest had a resting pulse rate of ~75 bpm and an initial core temperature of ~37°C.



The subject commenced exercise and was instructed to stop after a warm-up period of approximately 7 minutes. During the warm-up period, the subject's heart rate rose to stabilise at ~130 bpm. The core body temperature, after an initial period of compensation, rose progressively and stabilised at 37.5°C during the period of rest between the exercise phases. Heart-rate during the rest period showed a rapid recovery to ~110 bpm. There is evidence of slight cooling taking place during the rest period. On commencing the second phase of the test, heart rate increased rapidly to ~135 bpm and then increased slowly to reach a maximum of 170 bpm. Core body temperature increased steadily until the physician withdrew the subject at 38.6°C.

Neglecting heart rate monitor spikes attributed to electrode connection problems, all subjects were observed to be within safe heart rate limits. In generalising the trial observations, the primary risk factor for the test subjects was exceedence of safe core body temperature limits. It is noted that even where individuals attempted to pace themselves and reduce their energy expenditure, there was still evidence of heat gain. As an example, the figure overleaf graphs core body temperature characteristic and treadmill odometer pulse rate for a trial conducted at 29°C BET.



As a point of detail, during the second phase of the trial, the subject witnessed some discomfort from the hot air training model filter self-rescuer and compensated by progressively reducing his walking pace. Over a period of approximately 25 minutes, the subject, an experienced rescue brigadesman, reduced his walking pace by one third and substantially reduced the rate of core body heat gain. However it is noted that thermoregulation was still not achieved. This observation of progressive loss of thermoregulation during exercise held for all subjects. Related studies on the impacts of pre-warming of rescue brigadesmen by Hanson and Booth [2000] conducted by MRSL demonstrated comparable heat gain behaviour. In both of these studies the subjects were not acclimatised.

The question as to whether the escape respiratory protective devices used in mining contribute significantly to thermal burden, and hence rate of heat again, is more difficult to answer. The method used to assess this was to statistically compare the body temperature rise characteristic observed in phase one (no self-rescuer) with that of phase two (FSR/SCSR self-rescuer worn). A variety of statistical tests were employed. The overall conclusion was that any heat gained from these devices via the thoracic cavity was secondary to that involved in exercising under the prevailing conditions of heat and humidity. However this conclusion has a significant caveat - the soda lime hot air training model used in the trials had a relatively short life and achieved modest peak temperatures, and would not be representative of a filter self-rescuer worn in a high CO concentration atmosphere for extended periods. There is anecdotal evidence from mine incidents that wearers have witnessed significant discomfort at CO concentrations of 1% and above. Investigation of the Moura No. 2 colliery explosion in Australia, 1994, confirmed the potential for intense heat to be generated by filter self-rescuers.

In regard to chemical oxygen SCSRs, heat gained from the device during use has a complex physiological response when combined with the effects of breathing pure oxygen under severe climatic conditions. Breathing pure oxygen is postulated to reduce heart rate but not to otherwise reduce significantly heat build up within the body. One important observation in the deployment of

SCSRs was that recorded run-out times were all below the nominal duration specified at 30 L/min flow rate. There was also an indication that run-out time was adversely affected by the severity of the climatic conditions. These observations were however based on a small sample set.

A review of the scientific literature was undertaken to identify tolerance limits for breathing hot inspired air. Work conducted on behalf of the Japanese mining industry experimentally determined inspired air temperature limits for a test group over a range of relative humidity and breathing rates. Essentially, tolerance is determined by the heat content of the inspired air (enthalpy). At low air humidity, dry bulb temperatures of 90°C can be tolerated. However, the maximum temperature that can be tolerated is reduced for humid air. A limiting wet bulb temperature of 53°C is observed for most subjects. The effects of dehydration on the ability of subjects to tolerate hot inspired air require further investigation.

Summary of Trial Key Results

The foregoing observations, taken together with the results from the various statistical analyses, can be summarised as follows:

- In a range of climatic conditions ranging from 27°C to 37°C (air fully saturated), <u>all</u> subjects were withdrawn inside one hour of entering the chamber. In some subjects, an increase in core body temperature of 2°C was observed after a total of 30 minutes of exercise.
- During the trials, exceedence of the core body temperature limit (38.5°C) was the predominant reason for withdrawal. In nearly all cases, the subjects' core temperatures would have continued to rise above 38.6°C had they continued to exercise. This could have implications for emergency evacuation planning.
- None of the test subjects could be regarded as heat acclimatised, but all had levels of cardiovascular fitness meeting the statutory requirements for rescue brigadesman duties.
- Subjects self-paced themselves at between 2-4 km/h, but in all cases, core body temperature continued to rise during exercise. Only limited cooling took place during the short rest breaks. Even at the lower test chamber temperatures, restoration of normal core body temperature would probably require subjects to rest for several tens of minutes.
- There was no clear evidence that the test respiratory protective devices exacerbated thermoregulation and heat strain risk. However, the limits of tolerance for breathing hot inspired air and risk of premature removal are stressed.
- The average total distance covered during the test runs was 1448 m. This comprised the sum of the distances covered in the 'warm-up' and 'escape' phases. The maximum distance covered by any subject was 2350 m. The minimum distance covered was 590 m. The total distance covered was influenced strongly by chamber temperature.
- Based on two methods of regression analysis, the maximum distance projected for the upper and lower temperatures were as follows:

Temperature	*Regression Method 1*	*Regression Method 2*
27°C BET	1945 m	2335 m
37°C BET	785 m	1015 m

  It is noted that these distances apply to test subjects that had no pre-warming. Any significant pre-warming would reduce these distances.
- The mean rate of core body temperature rise observed was 0.07°C per minute within a range of 0.03 - 0.15°C per minute. (Limited scale tests in a hot US mine indicated an increase in core

temperature of 0.04°C per minute. The difference may be accounted for by the severity of climatic conditions and work rate.)

- No measurements could be made of typical metabolic rate whilst exercising on the mechanical treadmills. Estimates were obtained from scientific literature. The treadmill speed and effort incurred were considered appropriate to negotiating typical rough roadway surfaces underground.
- The observed run-out times for SCSRs varied from 10-25 minutes, with equivalent distances of between 560m and 1400m covered wearing the SCSR. Regression analysis indicates a reduction in SCSR run-out time of between 30-90 seconds for each 1 °C increase in BET. However this is based on a small data set.
- Temperature fluctuations and stratification of chamber temperature were observed. Whether thermal stratification increases individual thermal stress response is not clear.
- Only a limited subset of heart rate data was obtained, due to electrode connection problems. The mean heart rate recorded during the rescuer wearing phase was 156 bpm.
- It is reasonable to suggest that if a larger scale study of temperature sensitivity were conducted, comparable trends to breathing apparatus safe wearing times would be observed.
- Extrapolation of the findings to the general underground workforce is not straightforward. The test subject cohort utilised was not acclimatised. The regular underground workforce at UK deep mines would be acclimatised. However, the test subjects were considered representative of otherwise fit but unacclimatised mine staff and visitors.
- The mean speed of egress for the subject group was 3.3 km/h. This is also the most efficient walking speed when wearing heavy footwear. The analysis did not include assessment of the impacts of low visibility on speed of egress.

Application of the Research Work

One of the key issues of planning escape or rescue of casualties in long tunnels, without access to fresh air zones, is the ability to determine the margins of safety, under prevailing conditions, to extricate personnel without unacceptable risk. Critical parameters in this regard are the oxygen costs of the escape or rescue and the physiological strain resulting from hot, humid atmospheres, possibly compounded by low visibility. The emphasis of this study has been the qualification of thermal endurance limits. The limited tolerance of subjects to hot and humid conditions identified by this research may require reappraisal of escape and rescue assumptions used in mine and tunnel emergency planning.

Areas of potential focus include forced evacuation through return airways of coalfaces, or, seeking to evacuate blind headings ventilated by ducting. In order to minimise explosion risk in an emergency, electricity is isolated and underground transport systems are unavailable. In certain scenarios, such as fires in the intake side of production units, escape through return airways on foot may be the only option available. The energy intensity of modern coalfaces, taken together with water evaporation and coal/strata heat contributions, can substantially increase the return air effective temperature. Similarly, air returned along a single entry heading imposes an increasing level of climatic stress. The research findings suggest that the risks associated with these emergency scenarios may warrant reappraisal.

Development of guidelines that protect the whole mine workforce, whether they work regularly or infrequently underground, is not straightforward. Furthermore, the protection of persons who are most heat intolerant could possibly entail adopting conservative and restrictive heat stress limits. A few pointers are noted in this regard. Assessment of heat stroke in the South African gold mining industry by Stewart [1982] suggests that occupational incidence of heat stroke increased for ages >40. Kielblock et al [1982], commenting on the same industry, cite annual incidence rate of heat stroke morbidity and mortality increasing rapidly for wet-bulb temperature >34°C. In terms of the relationship between BET and productivity, Pickering and Tuck [1997] state that adverse effects on work efficiency commence at a BET of 27°C, and productivity declines noticeably at BETs >30°C.

Predictive safety models, such as ISO 7933 [1989], are used to predict the safe group response (i.e. 38 °C maximum core body temperature) for 95-99% of the population. When actual workplaces in the mining industry have been evaluated, it has been shown that many workplaces significantly exceed the ISO modelled safety limits [Havenith 1997]. However, at these workplaces, few heat related problems were encountered. Havenith [1997] conjectures that underground workers are fitter than the general population and are also acclimatised, resulting in lower strain for the same climatic stress. However, the benefits of acclimatisation are greatly diminished if members of the workforce are subject to hypohydration (significant body fluid deficit). In this case, the response of unacclimated and heat-acclimated personnel who are hypohydrated is broadly similar. This reinforces the critical requirement for underground staff to have ready access to drinking water, and for drinks to be taken at regular intervals in hot and humid conditions. This unfortunately, is not an option in a prolonged escape.

Further Work

The research programme has highlighted a number of critical issues and requirements, which suggest further research may be appropriate:

1. The test observations were all associated with unacclimatised personnel. There is a specific need to reproduce the tests using physically fit, acclimatised mine personnel. The concerns of HSE's Research Ethics Committee have been noted. In order to respond to these concerns, an approach could utilise part-time brigadesmen who are normally employed at the mine. A medical examination could be arranged for the test date. The part-time brigadesmen could then be selected as being reasonably representative of the mine workforce.
2. The metabolic rate of subjects using the treadmills was not measured. It would be useful to confirm the typical metabolic rate using laboratory calorimetric methods. Metabolic rate has a fundamental impact on heat stress response and escape oxygen cost (SCSR run-out time).
3. The application of safe havens has been progressed at a number of UK underground mines. Safe havens may provide a suitable location to rest and recover within a staged evacuation procedure. There is a need to determine how safe haven microclimate influences cooling. This could impact on the design, location and use of safe havens.
4. There is a requirement for an SCSR oxygen consumption prediction model specifically for use in high heat and humidity. The observations of SCSR run-out time, based on a small data set, provide some limited evidence to suggest a relationship between run-out time and climatic stress. A tailored extension to the work programme could specifically address this issue.
5. Acclimation of personnel is influenced by hydration state. It would be valuable to determine if the ability to recover and rehydrate, by making drinking water available, possibly at safe havens, materially reduces heat stress risks. This issue is also of critical importance to mines rescue staff.
6. Current test standards for escape respiratory protective devices do not account for dehydration and wearer discomfort. There is a requirement to reappraise FSR/SCSR thermal behaviour to assess whether standards should be revised in order to provide a better estimation of wearing duration limits.
7. A further requirement is to determine under what climatic conditions mineworkers are able to walk for a nominal 2 hours whilst wearing a FSR and maintain thermoregulation.
8. There could be some benefit in contrasting safe wearing times for various types of breathing apparatus, in physiological response and risk terms, with safe endurance limits for escape

respiratory protective devices. An objective could be to determine whether a generalised wearing time model could be developed to help industry apply breathing apparatus and respiratory protective devices in thermally stressful environments.

9. It is recommended that thermal physiological limits are formally incorporated in mine/tunnel risk assessment and escape planning. This recommendation also applies to a wider range of industries, which impose stressful conditions of heat and humidity during specific activities (e.g. entry and maintenance activities within confined spaces).

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Use of Self Rescuers in Hot and Humid Mines

1. INTRODUCTION

The concept of self-rescue is premised on the assumption that underground mineworkers will have the physical and mental capacities required for self-rescue and in-seam rescue. There is a recognised research 'gap' concerning the practical limitations, and ultimately personal endurance limits, associated with the extended wearing of mining industry respiratory protective devices under high physiological stress conditions. This has implications for those who have responsibility for the design of emergency response strategies predicated on seeking to directly evacuate hot and humid mines. There are a number of related issues to be considered when preparing an emergency preparedness strategy:

- Is it possible to devise mine-wide escape strategies, which account for the limitations of respiratory protective devices?
- What are the impacts of seeking to evacuate the mine where there are long walking distances, adverse gradients and high heat and humidity conditions?
- Is it possible to provide effective and realistic training, accurately simulating the respirator's heat release under high carbon monoxide conditions?
- How can the use of self-rescuers be integrated with safe havens?
- What additional support technologies are required to aid escape, and can they be put to effective use in an emergency situation?

Throughout the UK underground mining industry, the primary response to a major emergency is to evacuate the mine. In the case of fire or explosion, the filter self-rescuer (FSR) provides some protection against carbon monoxide poisoning. It is a requirement of mine owners and mine managers to determine the most appropriate means of evacuation support and training. There must be an appropriate response to the assessed risks at the mine and the atmosphere present after a fire or explosion. This includes the need to consider the selection of self-rescuers and the possible provision of safe havens. Managers may also wish to seek advice from the Health & Safety Executive (HSE). The Escape & Rescue from Mines Regulations 1995, Reg 10 ACOP 46, states that "Managers should seek the advice of a Mines Inspector if they are in any doubt as to the suitability of a type of self-rescuer.

In order to provide an improved understanding of the interactions between the wearing of escape respiratory protective devices and the prevailing thermal environment, an integrated programme of research was proposed. Essentially this involved:-

- a re-examination of relevant physiological heat stress literature
- consideration of the underground climate conditions encountered
- undertaking investigations towards developing an improved simulation of hot air breathing effects, and

- carrying out a programme of climatic chamber wearing trials using both filter self-rescuers and chemical self-contained self-rescuers (SCSRs) in conditions of high heat and humidity.

The wearing trial component of the programme, which involved volunteers being subject to controlled physiological stress, was reviewed by and subsequently received the approval of HSE's Research Ethics Committee (ref. ETHCOM/EG/01/16, 27-11-2001). Any requirements for information on the submission to HSE's Research Ethics Committee were to be addressed to Dr RG Rawbone, Medical Secretary of the Committee.

2. RESEARCH OBJECTIVES

The **primary objectives** of the work were:

- to improve knowledge and guidance on the selection and use of self-rescuers appropriate to prevailing deep mine environments in the UK.

- to help identify escape strategies which may be suitable for distant working, low visibility and high heat stress conditions.

Statutory Instruments, 1995, Number 2870, Health and Safety, The Escape and Rescue from Mines Regulations, 1995, Regulation 10, 'Arrangements for Escape', prescribes a duty on the owner of every mine to provide suitable self-rescuers for all persons going below ground, and where necessary, safe havens or facilities for the exchange and recharge of self-rescuers. The associated Approved Code of Practice and Guidance (ACOP) to The Escape and Rescue from Mines Regulations specifies that managers should seek the advice of a Mines Inspector if they are in any doubt as to the suitability of a type of self-rescuer (L 71, s 46). The ACOP (s 49 et seq) also specifies that the selection of self-rescuer, and the need to consider the provision of a safe haven, will need to take account of the results of the risk assessment and the atmosphere present after an incident. The ACOP places an additional duty on mine owners to ensure, where appropriate, that all persons routinely working below ground include the option of hot air experience in initial training and, by election, in five yearly refresher training.

The above legislative requirements and guidance place a significant duty on mine owners and mine managers to determine the most appropriate means of evacuation support and training. The central objective of the research programme was to systematically address these issues and provide additional information to complement guidance given in HSC Deep Mined Coal Industry Advisory Committee document 'Guidance and Information on Escape and Rescue from Mines', [2001].

3. DESCRIPTION OF KEY RESEARCH TASKS

The research comprised **three integrated modules** of work which collectively:-

- involved a re-examination of relevant physiological heat stress literature and industry conditions
- undertaking investigations towards developing an improved simulation of hot air breathing effects, and
- carrying out a programme of climatic chamber wearing trials using both filter self-rescuers and chemical SCSRs.

The activities within the respective research modules are summarised as follows:

RESEARCH MODULE 1: Literature review and scoping review of industry practice and climate conditions

This component of the work programme primarily involved reviews of literature in this field. Various emergency escape strategies were contrasted with reference being made to international practice and developments in self-escape. A second component of the literature review examined relevant aspects of heat stress and the use and testing of respiratory protective devices under hot and humid conditions. The general climatic conditions present in deep UK mines and representative seams were also reviewed. This was not a comprehensive survey, but rather, a selective report of the range of conditions associated with hot and humid working environments present underground.

RESEARCH MODULE 2: Simulation of high temperature breathing characteristic of FSR when subject to high levels of carbon monoxide

There is a legal duty to be able to provide training experience of the hot air breathing characteristic of a filter self-rescuer. It is clearly not permissible for subjects to experience the use of FSRs using an atmosphere containing high levels of carbon monoxide and alternative means of simulating the hot air characteristic must be found. The research activities within this module included:

- Reviewing the inhalation temperature behaviour of the FSR, with reference to manufacturers' EN404:1993 test data (as available).
- Examining training requirements and associated safety and practicability issues.
- Investigating hot air simulator configurations based on:
    - (a) Heat release from soda-lime or alternative exothermic chemical agents (where heat release is a function of respiration rate/work rate), and
    - (c) Intake air preheating based on an air heater-heat exchange unit design.
- Application of the hot air breathing unit(s) in the climatic chamber trials.
- Identifying possible industry options for hot air training.

RESEARCH MODULE 3: Climatic chamber wearing trials of FSRs and SCSRs under high physiological stress conditions

This was the largest component of the research programme, involving a pool of 25 volunteers, with medical supervision and medical guidance on experiment design and procedure provided by Business Healthcare Limited. A key issue addressed was whether it was possible to maintain adequate thermoregulation during an underground evacuation in hot and humid conditions, whilst wearing an escape respiratory protective device. The filter self-rescuer apparatus, under high carbon monoxide concentrations, substantially increases the inhalation air temperature to the wearer, increasing the thermal burden on the body. However, thermoregulatory stress response is dependent on a number of individual characteristics including heat acclimatisation status. The form of clothing may also have a significant impact. Within the wearing trial programme, it was recognised that consideration should be given to the following:

- Ensuring subjects presented, as far as possible, a representative range of ages, body weights and cardio-vascular fitness levels.
- The need to represent the requirement of seeking egress from long headings.
- Incorporating consideration of escape involving adverse gradients in conditions of high heat and humidity, possibly involving staff without acclimatisation.
- That the additional heat burden from the respiratory protective device was accounted for in any wearing trials.

A climate-controlled chamber at Selby Mines Rescue Station was used to develop a controlled saturated environment of between 27°C and 37°C (100% humidity). This provided a range of test temperatures with fully saturated atmospheres. Treadmills were utilised to develop an appropriate work rate. The hot air training apparatus resulting from Research Module 2 was used in the chamber trial programme. The climatic chamber wearing trials focussed on the deployment of the MSA W95-FSR filter self-rescuers, with a lesser number of comparative tests conducted using approved SCSR devices (MSA SSR30).

Risk assessment, experimental design and the prescribed limits for terminating the experiment were critical considerations. Physiological monitoring was employed throughout all trials, which involved continuous real-time monitoring and recording of subject heart rate and core body temperature. Physiological withdrawal criteria were set at 38.5 °C core temperature measured via aural measurement and a heart rate in excess of 180 beats per minute. An experienced occupational physician supervised subjects throughout the trials. As noted earlier, the experimental protocol received the approval of HSE's Research Ethics Review Committee.

4. INITIAL DISCUSSION ON HEAT STRESS ISSUES

In order to help devise a representative physiological test regime, consideration was given to various aspects of underground working, heat stress measurement and disorders, and individual thermal stress response. An initial discussion on heat stress issues is given here, although it is noted that further comment is made at other points in the report. Since the bulk of the research programme is essentially concerned with investigation of thermoregulatory breakdown, it is also useful to provide a simple description of the model of thermoregulation in man, together with listing factors which impact on heat stress.

4.1 Workplace Issues

Whilst mineworkers generally have a high tolerance of arduous mine conditions, there are many contractors, visitors and possibly management staff who have somewhat lower levels of cardiovascular fitness and may lack heat acclimatisation. In the event of an emergency taking place towards the end of a shift, then it is likely that men would be in a partially dehydrated state. This situation will be compounded for men who have been undertaking tasks with a high work-rate. In this case, their core body temperature may be close to its maximum for the shift. The acclimatisation response to heat requires frequent exposure and is rapidly lost on leaving the hot area. In an emergency there is no opportunity to reduce physiological heat stress by resting prior to using the respiratory protective device. The requirements to undertake evacuation at a steady, paced rate may be compromised by fear and disorientation. Training can help increase this preparedness and ultimately moderate metabolic rate in an emergency situation.

Some mines have an environment consistently close to 100% air saturation. Any loss of ventilation acutely affects the body's ability to be cooled effectively. Whilst selection of rescue personnel can be undertaken to screen out illness and dehydration, a small but significant fraction of the mine workforce would at any time have increased proneness to experiencing heat strain associated with illness. The filter self-rescuer apparatus, under high carbon monoxide concentrations, substantially increases the inhalation air temperature to the wearer, and most probably the breathing resistance, making breathing uncomfortable and adding to the thermal burden on the body. In an emergency evacuation, staged rests may help the body to thermoregulate and lose body heat. However, the motivation to escape may be such that resting is ignored. Traversing uneven or sloping mine floors, particularly drifts, will be associated with a significantly higher work-rate. Travelling up significant gradients in a return airway may present high physiological stress. The Health and Safety Commission's Guidance document [2001] cites elevated risks situations to include:

- Single entry headings;
- Longwall faces with roadways over one kilometre long;
- Hot and humid roadways;
- Steep roadways.

Heat strain involves a complex interaction of mine environmental conditions (temperature, humidity, radiation, air velocity) metabolic heat production rate and clothing. Individual tolerance to heat can vary widely. The effective heat strain on the body will depend on these conditions. Individual response depends on age, fitness, acclimatisation, hydration, and general health. If heat cannot be lost to the environment, heat build up will occur within the body (heat storage). Mines rescue staff have maximum safe wearing times for SEFA breathing apparatus calculated from empirically derived tables. Body pre-heating associated with walking inbye has been shown to have a significant contributory effect in terms of increase in core temperature of rescue brigadesmen [Hanson and Booth 2000].

In terms of selection of subjects for climatic chamber endurance tests, the cohort should be reasonably representative of the workforce population, including less heat tolerant individuals. A hypothesis was advanced that cooling from the respiratory tract would be reversed (i.e. heat gain) or greatly reduced when the filter self-rescuer is operated in a high carbon monoxide concentration environment. The risk of heat exhaustion is linked to a number of individual characteristics. The body-mass index (BMI) calculated as BMI=weight/height^2 has a significant correlation with heat exhaustion risk. Accordingly, subjects with high BMI needed to be considered (BMI greater than 30). Similarly, it was also necessary to consider whether subjects representative of older workforce members should be included.

Underground clothing is likely to be standard, hot climate workwear (boots, shorts, T-shirts, helmet). However, visitors and management staff may be more likely to wear overalls. Significant clothing, such as a combination of overalls and underwear, can act as a barrier to heat dissipation and reduce the effective body surface available for evaporative cooling. This needs to be taken into account.

Experimental scenarios to simulate escape activities primarily involve walking with varying gradients and floor conditions. In practical circumstances it would be reasonable to assume that the individuals may have eye irritation from smoke and must also make their way out in low visibility conditions. Experimental circumstances cannot however cover the use of irritant smoke. In practice it would also be difficult to rule out the possibility of escaping workers offering assistance to their injured colleagues. Any intervention to partially support or assist injured colleagues could dramatically increase heat burden and individual heat stress.

4.2 Factors involved in human heat stress

There is a wide range of factors that have an impact on human heat stress response, but which can be summarised as follows [Schneider 1999, Zenz et al 1994]:

External Factors:

- Air temperature and humidity
- Temperature of solid surroundings (radiant energy)
- Temperature of the skin
- Air motion
- Type of clothing worn
- Time exposed
- Work factors (load, weight of equipment, pace)

Human Factors:

- Age, sex, race
- Size (mass, surface area)
- Degree of muscle activity
- Health status and individual fitness
- State of acclimatisation
- Psychological factors (incentives, rewards, discipline).

4.3 Heat Disorders and Health Effects

The human body has a limited capacity to adjust to extremes of temperature and humidity. The following summarises principal heat-related illnesses:

Heat stroke occurs when the body's system of temperature regulation fails and body temperature rises to critical levels due to uncompensated heat storage. This condition is associated with highly variable factors, and its occurrence is difficult to predict. Heat stroke is a medical emergency. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment. The primary signs and symptoms of heat stroke are confusion, irrational behaviour, and loss of consciousness, convulsions, a lack of sweating, hot dry skin, and an abnormally high body temperature, e.g., a rectal temperature of 41°C.

Heat exhaustion - the symptoms of heat exhaustion include headache, nausea, vertigo, weakness, thirst, and giddiness, and have some similarity with the symptoms of heat stroke. The condition responds readily to prompt treatment. Fainting associated with heat exhaustion represents a significant hazard where the subject may be operating machinery or controlling an operation that should not be left unattended.

Heat cramps are associated with performing hard physical labour in a hot environment. The cramps are attributed to an electrolyte imbalance caused by sweating and lack of water replenishment. Since sweat is a hypotonic solution (±0.3% NaCl), excess salt can build up in the body if the water lost through sweating is not replaced. Thirst cannot be relied on as a guide to the need for water; water must be taken every 15 to 20 minutes in hot environments.

Heat collapse - in heat collapse, the brain does not receive enough oxygen due to blood pooling at the extremities. As a result, the exposed individual may lose consciousness. This reaction is similar to that of heat exhaustion and does not affect the body's heat balance. However, the onset of heat collapse is rapid and unpredictable. To prevent heat collapse, the worker should be progressively acclimatised to the hot environment.

Heat rashes are the most common problem in hot work environments. Prickly heat is manifested as red papules which usually appear in areas where clothing is restrictive. Prickly heat is associated with skin that is persistently wetted by unevaporated sweat. In most cases, heat rashes will disappear when the affected individual returns to a cool environment.

Heat fatigue - one factor that predisposes an individual to heat fatigue is lack of acclimatisation. The signs and symptoms of heat fatigue include impaired performance of skilled sensorimotor, mental, or vigilance-based tasks. Mitigation of heat fatigue requires removal or reduction of the heat stress.

The following host factors are reported to increase risk of heat stroke:

- Lack of acclimatisation
- Obesity
- Poor physical fitness
- Fatigue

- Sleep deprivation
- Febrile illness
- Dehydration
- Acute and convalescent infections
- Immunisation reactions
- Conditions effecting sweating
- Skin disease (heat rash, sunburn)
- Drugs (alcohol, antihypertensives, caffeine)
- Past history of heat injury
- Past history of residence in areas with greater atmospheric cooling power
- Chronic disease (diabetes, thyroid, cardiovascular)
- Neurological lesions (hypothalamus, brainstem, cervical chord)
- Post surgery
- Recent food intake
- Sustained muscle metabolism.

4.4 Thermoregulation

Although the thermoregulatory mechanisms in man have not been fully explained, there is convincing evidence concerning the role of the hypothalamus as the temperature-regulating centre, which mediates heat loss through increased blood flow to the skin and sweating. Minard [1973] proposed a model for the thermoregulatory system controlling body temperature under conditions of heat stress. Minard structured the model as an analogue of an electrical engineering closed loop control system employing negative feedback proportional control. Whilst an electrical feedback system has limits as an analogy, it does permit primary physiological responses to be modelled quantitatively to a first order.

Feedback in the model is negative since the error signal is the difference between the input, the set point of the thermostat (37.0°C for the hypothalamus and 34.0°C for the skin), and the output, core body or skin temperature. It is reasonable to use a proportional control model because the central drive and effector responses (blood flows and sweat rate) are proportional to the error signal. In the absence of a heat load, the central drive is zero, output and input being equal. The model predicts that when equilibrium is reached under a given heat load, core temperature and mean skin temperature (output of the system) will stabilise at a level above the set point by an amount proportional to the load. The deviation from the set point is called the 'load error', and the effectiveness of the controller in temperature regulation depends on its sensitivity to the error signal, or gain. The gain factor is high in individuals with high heat tolerance, and increases with acclimatisation.

4.5 Heat storage

Heat storage is a change in the body's heat content. The rate of heat storage is the difference between heat production/gain and heat loss, and can be determined from simultaneous measurements of metabolism by indirect calorimetry and heat gain or loss by direct calorimetry. Since heat storage in the tissues changes their temperature, the amount of heat stored is the product of body mass, the body's mean specific heat, and a suitable mean body temperature. The body's mean specific heat depends on its composition, especially the proportion of fat, and is about 3.39 $kJkg^{-1}{}^{\circ}C^{-1}$ for a typical body composition of 16% bone, 10% fat, and 74% lean soft tissue.

The human body maintains a basic minimum rate of heat production of about 75 Watts, and about 120 Watts when awake but sedentary. As bodily activity increases, the rate of oxidation of food, with its attendant release of energy, must increase. Metabolic enthalpies (heat energy liberated in the body per g combusted nutrient) in $kJ.g^{-1}$ per food type are; protein 17, fat 39 and carbohydrate 17.5 $kJ.g^{-1}$.

The level of heat production for light work is of the order of 190 Watts, with the extreme value exceeding 700 Watts for heavy work.

Borudulin et al [2001] have reviewed heat exposure metrics and modelled the respective contributions of breathing, convection, radiation and sweat evaporation. At a metabolic rate of 165 Wm^{-2} and dry/wet bulb temperatures of 28°C/25°C, the contribution to cooling is typically as follows:

Breathing	8%
Convection	16.5%
Radiation	5.5%
Sweating	70%.

It is noted that a description of a first order linear model of heat storage, which takes place when thermoregulation has failed, is provided in the statistical analysis of trial results. This is based on a classical heat balance equation approach. It is shown that there is reasonable agreement between the model and the empirical core body temperature gradient data with elapsed physical activity time.

4.6 Effects of Clothing

Clothing an individual wears modifies thermal comfort and stability considerably. In hot environments or during heavy work, the body relies critically on heat loss through the evaporation of sweat. Clothes become a barrier to the evaporation of perspiration from the skin, and sweat evaporated from wet clothing is much less effective in removing heat from the body than moisture evaporated directly from the skin. The impact of garment sets used in the mining industry, represented as a ratio of surface area available for heat exchange by convection is cited as follows [McPherson 1992]:

No clothes	1.0
Shorts	0.95
Shorts and T-shirt	0.90
Long overalls	0.78

It is unlikely (and inadvisable) that workers would attempt to remove clothing during an emergency whilst wearing a filter self-rescuer. The risk of dislodging the self-rescuer and disturbing the mouth or nose seal would be high.

With impermeable clothing, direct heat loss by sweat evaporation is not possible. Additionally, any weight carried adds to the metabolic rate of workers, increasing the amount of heat the body produces. The net effect is potentially severe heat stress. Heat transfer through clothing is a function of the thermal resistance of the clothing and the temperature and humidity differential between the inner and outer surfaces. Thermal resistance of clothing is expressed in terms of "clo" units. One clo is defined as the equivalent to normal indoor clothing and is the clothing insulation required to keep a resting subject indefinitely comfortable within a standard test environment. The biophysics of clothing has become increasingly significant in recent years, using an interdisciplinary approach (physiology, psychology, physics, clothing design, and textile science) to relate human work efficiency and comfort to a specific task in particular environments. Example standards relating to protective clothing and equipment include the US National Fire Protection Association (NFPA) Technical Committee on Fire Service Protective Clothing and Equipment, and the American Society for Testing and Materials (ASTM) F23 Committee on Protective Clothing. Hanson [1999], Havenith [1999] and Parsons [1999] provide further reviews of standards.

NIOSH studies of workers wearing chemical protective clothing and firefighters' ensembles have indicated that heat stress is a serious consideration [US Department of Labor, 2002]. Significant physiological stress was observed, even at low work intensities (30% of maximum work capacity involving level walking at 5.4 km/hr) in a thermally benign environment (23°C and 55% RH). With the chemical protective ensemble, worker tolerance time was reduced by 56% as compared to light work clothing only. Elevated rectal temperatures (in excess of 39.0°C) were observed in three of the nine subjects. With the heavier firefighters' ensemble, tolerance time was reduced by 84% as compared to light work clothing only and heart rates averaged 25-50 beats per minute higher than with the lightweight work clothing. At higher work intensities (60% of maximum), tolerance time was decreased by as much as 96%.

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SECTION 1:
REVIEW OF UNDERGROUND CLIMATE CONDITIONS

The progression towards deeper, more extended workings in mature mining industries can generally be associated with an increasing difficulty in maintaining tolerable working conditions. This is particularly the case where there is high productive capacity plant installed and reliance placed solely on conventional ventilation methods. This section of the report provides a general overview of climatic conditions underground, as reported by a number of historical UK surveys, and from selective data drawn from more recent surveys. There also exists a significant amount of related literature attributable to other national mining industries but this is not reported here.

Allen [1976] reported the results of a UK national survey of thermal conditions (effective temperature American, ETA) observed at longwall districts and headings at statutory measurement points. For 241 collieries, 710 headings were surveyed, where;-

- 13.1% had a maximum ETA of 24-27°C, and
- 2.7% a maximum ETA of >27°C.

The respective figures for longwall districts were 10.2% and 3.7%.

A smaller survey of individual workplaces undertaken by Graves et al [1981] indicated;

- 14.9% of development headings had an ETA of 24-27°C with
- 4.6% having an ETA of >27°C.

Figures for longwalls were 25.6% and 5.3% respectively.

A slightly later study by Graveling and Nicholl [1983] concentrated on machine operator workplaces in headings and gate ends, where mean peak ETAs were observed to be 29.1°C and 29.4°C respectively, with a highest effective temperature of 32.3°C recorded.

The contraction observed within the UK deep mine coal industry has resulted in some of the remaining mines having higher temperatures than those reported above. A number of recent studies have examined approaches to controlling mine climate [e.g. Shead and Tuck 1997]. These studies provide indicative data for environmental conditions at specific sites. The Industry Working Group established to examine aspects of hot and humid conditions, as reported by a Leeming and Fifoot [2001], observed specific conditions as follows:

Underground Location	Dry Bulb Temperature, °C	Wet Bulb Temperature, °C
Site A: Development Inbye Outbye	 36 39	 28.5 29
Site B: Longwall Face Return Gate, Outbye	 38	 34
Site C: Longwall Face Mid Face	 33	 31
Site D: Longwall Face Return Gate, Outbye	 33	 27
Site E: Development Face Outbye	 31 33	 24 28
Site F: Development Face	 36	 31

Heat measurements for working places are also reported at meetings of the Environmental Advisory Committee convened by HM Inspectorate of Mines. The table below, reproduced from the minutes of the meeting of the 13th November 2001, lists those working places which exceeded 30°C within a period of 6 months:

Mine	Working Place	ET(A) °C May 01	June 01	July 01	Aug 01	Sept 01	Oct 01
Harworth	22's T/Gate D	35.92	33.56	31.00	32.24	-	-
	22's R/Gate D	30.67	30.81	31.00	-	31.31	32.02
	19's R/Gate D	-	30.87	-	-	-	-
	17's Face F	-	-	-	30.48	-	30.25
Maltby	T16's	31.20	32.10	31.20	31.50	32.70	31.90
	T106's	-	-	33.30	33.00	32.70	32.80
Stillingfleet	Moreby Return D	-	-	-	-	31.00	-
	308's T/Gate D	-	-	30.00	-	-	-
Thoresby	192's F	30.30	30.80	31.60	30.00	31.80	31.10
	190's L/Gate D	30.00	30.30	30.90	31.20	31.90	32.00
	190's R/Gate D	-	31.20	31.70	31.00	31.40	31.80
Welbeck	310's F	-	-	-	-	-	31.90
	307's F	32.30	30.40	30.40	30.40	-	-
	312's R/Gate D	-	-	31.80	31.10	32.60	32.40
	312's L/Gate D	-	-	-	-	32.80	32.40

The impacts of high horsepower coalface production equipment and the water utilised for cooling purposes can be gauged from a coalface heat survey taken in mid-2002, as follows. Related climatic modelling is a subject of ongoing research [ECSC 2002].

Heat Survey Location	Dry Bulb Temp, °C	Wet Bulb Temp, °C	Humidity %	ETA
Main Gate, outbye pantechnicon	34	30	75	28.0
Face, 10m from main gate	35	31	75.5	29.3
Face, mid point	36	34	87	32.8
Face, 10m from tailgate	38	36	88	35.9
Tail Gate, 10m outbye of curtain	38	37	94	37.3

The Institute of Occupational Medicine, in a jointly sponsored study by RJB Mining (UK) Ltd, and HSE, undertook a survey of three hot and humid mines and one cooler mine, which included measurement of core body temperature (via the aural canal) and heart rate of miners at work [Hanson et al 2000]. This study, intended as a validation study for the Code of Practice proposed by IOM for work in hot and humid conditions in coal mines, indicated the following for the mines surveyed:

1. Environmental conditions at the three hot mines showed only small differences at comparable measurement locations.
2. The majority of effective temperatures measured at workplaces were within a range of 26°-32°C.
3. At a small number of workplaces, effective temperature reached 40°C.
4. Mean core body temperature increased by 0.04°C per °C increase in BET.
5. Core body temperature measurements exceeded 38°C for 13% of the measurements recorded, and exceeded 38.5°C in 7% of the measurements recorded.

In summary, all deep laterally extended mines receive heat contributions from a variety of natural and production process sources [e.g. Pickering and Tuck 1997]. Outwith employing refrigeration, heat control options broadly comprise increased ventilation and preventing unwanted heat transfer to intake air streams, possibly involving changes to equipment siting and duty [Leeming and Fifoot 2001]. On consideration of the climatic conditions currently observed underground, and the possible exacerbation of these conditions in a developing fire situation, the range of chamber test temperatures used at Selby is considered to be appropriate.

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SECTION 2

DEVELOPMENT OF A RESPIRATORY PROTECTIVE DEVICE HOT INSPIRED AIR SIMULATION UNIT

This section of the report examines the work undertaken to develop a hot air simulation unit for use in the climatic chamber trials. Options available for providing hot air training on a wider industry basis are also discussed. The section is sub-divided into two parts:-

A discusses the physiological impacts of wearing personal respiratory protective devices and limits of tolerability for hot inspired air

B reviews the work undertaken to examine options for a hot inspired air simulation unit.

A: REVIEW OF RPD IMPACTS AND HOT AIR SAFETY LIMITS

The requirement for a hot air simulation unit was predicated on two requirements:

- Training Device

  The objective is to develop or identify devices appropriate to providing wearing experience of the hot inspired air effects associated with an operating FSR or SCSR in a high CO content atmosphere. In this case, the intention is to offer the mine workforce short-term experience of any respiratory tract discomfort resulting from breathing hot air.

- Hot Air Burden During Trials

  The inspired air from a filter self-rescuer operating in high ambient CO concentrations will become uncomfortable. It is speculated that the additional heat burden might have a statistically significant effect where the individual is escaping in severe climatic conditions, say basic effective temperatures greater than 35°C. Under normal circumstances, breathing heat loss from the thoracic cavity is substantially less than that from the evaporative heat loss from sweating. However, in extreme climatic conditions, possibly associated with hot and humid conditions underground where ventilation has been disrupted, then the ability to thermoregulate through the sweat mechanism could be seriously compromised. At this point, the additional heat burden from a hot filter self-rescuer would augment body heat storage and the progression to heat stress. For this reason it is argued that the heat load presented by the hot air simulation should be made as demanding as possible.

Contrasting these two requirements, a distinction is made between experiencing respiratory tract discomfort and the hot air burden contribution to thermoregulatory breakdown. As part of the assessment of risk arising from subjecting hot air device wearers to excessive inspired air temperature and heat content, preliminary studies were undertaken to establish safety limits for inhalation of hot air, together with a general review of physiological impacts.

1. Physiological impacts of wearing a personal respiratory protective device

There has been wide-ranging research on the physiological effects of the use of personal respiratory protection, including wearing properties and subjective assessments of discomfort. Hettinger et al [1997], in a programme of work for the European Commission, commented as follows on the need for training to ensure that respiratory protective devices are used correctly:

"The special importance of adequate training, which was often found to be insufficient in the workplace-related study, was particularly apparent with regard to faulty use and the many different manipulations performed by employees on the filtering devices. Training and regular (repeated) instruction ... must therefore be performed systematically. Only in this way can the filtering device protect the employee in the expected manner."

The need for effective induction training and follow up training has been widely accepted within the international mining industry for escape respiratory protective devices. Familiarity with the respiratory protective device is also likely to reduce the psychological strain reaction and result in a lower level of cardiovascular strain. However, there is virtually no evidence of training programmes containing simulation of the hot inspired air effects potentially associated with the wearing of these devices. A brief overview on wearer general physiological impacts is presented here.

The literature cites respiratory pressure difference, and its effect on pulmonary and cardiovascular parameters, as being an important limiting factor on performance whilst wearing filtering devices. [Steinhaus 1989, Fuerst 1983]. Dead space may also be an issue.

The increased resistance to inspiratory and expiratory flow that a respirator imposes can cause an increase in tidal volume, a decrease in breathing frequency, and a decrease in minute ventilation, with a concomitant decrease in alveolar ventilation [Deno et al 1981, Harber et al 1989, Hermansen et al 1972]. In certified respirators, these effects have been shown to be small and generally well tolerated in healthy individuals, and even in persons with impaired lung function [American Thoracic Society, 1996]. The increase in dead space associated with a respirator will tend to increase minute ventilation due to the rebreathing of expired air. This added stress, which although variable and dependent on the type of respirator and the individual, is usually not a limiting factor [Harber et al 1982, Harber et al 1991, Morgan 1983].

During submaximal exercise, the effects on work performance from wearing most respirators seem to be small. When submaximal work load was held constant, several studies showed that heart rate did not appear to be affected by a respirator [American Thoracic Society, 1996]. Other studies show, depending on the level of energy expenditure, a mean increase in working pulse rate of up to 11 beats per minute accompanied by a reduction in respiratory rate and an increase in tidal volume, with study inhalation pressure differences in the range of 2 - 24 mbar [Hettinger et al 1997].

Increased resistances and dead space can lead to decreased (by approximately 10%) maximal work performance [American Thoracic Society, 1996]. In industrial settings, Hettinger et al [1997] observed maximum inhalation pressure differences in devices in use of up to 40 mbar due to excessive respirator loading. In the UK, work by Bentley et al [1973] showed that 90% of a test population of 158 rescue brigadesmen did not experience discomfort if the pressure swing at the mouth could be kept below 17 cm H_2O equivalent, and the mean inspiratory work rate did not exceed 1.37 Joules per litre (0.14 kg/l). Love et al [1976] extended this work to men over the age of 45, where it was concluded that the acceptable level of breathing resistance established for younger men could also be applied to older workers.

The attribution of heat stress due to respirator wear in physiologic studies is relatively limited, and does not generally cover devices which present a significant thermal load. In one study [Caretti 2000], five subjects completed treadmill walking trials in a warm environment (34°C dry bulb and 25°C wet bulb) with and without a respirator (a powered air-purifying respirator). Subjects wore one-piece cotton coveralls over shorts and a T-shirt for both test trials. In general, core temperatures (T_C) increased throughout heat exposure trials. However, no differences in average core temperatures, heart rates, mean skin temperature (T_{SK}), sweat rates, or heat storage rates were observed between the unmasked and masked tests under these conditions. The respirator thermal burden in these trials was however relatively small compared with that potentially arising from an escape respiratory protective device.

Whilst the physiological response to the wearing of SCSRs has been extensively studied using breathing machines at moderate work and temperature conditions, there is relatively limited reported research on the characteristics of SCSRs at high work rates and extreme temperatures. Takahashi et al [1997] have suggested that some SCSR designs experience a rapid increase in CO_2 when the metabolic rate of the user exceeds the absorbent capacity of the units. This can lead to ventilatory distress and early rejection of the SCSR in use for some individuals (acute hypercapnia response). Takahashi et al [2000] suggest that there is up to 20-1 range of sensitivity in individual ventilatory response to high inhaled CO_2 levels and that, accordingly, a recommendation be made for standards for SCSR CO_2 limits to be reduced to a 2% design standard, with a long-term objective of a 1% design standard.

2. Limits of Tolerability for Breathing Hot Air

The maximum tolerable temperature is a complex issue, with the heat energy content of the air being an important parameter. The total air energy, the air enthalpy, is the sum of both the heat energy of dry air and the heat content of vaporised moisture in the air. Psychrometric data in **Figure 2.1** indicates that lines of constant air enthalpy follow almost exactly the line of constant wet bulb temperature. Therefore, wet bulb temperature provides a relatively accurate measurement of the heat (energy) content of air. The specific enthalpy for dry and saturated air, plotted in **Figure 2.2,** indicates that saturated air enthalpy increases rapidly above ~50°C.

The extent and depth of any thermal damage depends ultimately on the intensity and depth of tissue heating, the amount of energy transferred from the source and the ability of the local circulatory system to remove heat [Diller 1994, Moritz and Henriques 1947, Stoll 1967]. In submerged hot-water scald burns, for example, temperatures of 46°C can rapidly cause major damage due to intimate thermal contact. However, hot dry air, in spite of its low enthalpy will have some discomfort and may induce naso-pharyngeal spasm, leading to removal of a respiratory protective device. The issue of wearing discomfort of FSRs at very high CO ambient concentrations has, for obvious reasons, not been systematically researched.

Various researchers have investigated the effects of elevated inhalation temperature on the human body [Takahashi et al 1999]. One notable finding is that there is a close correlation between the inspired wet bulb temperature and tissue temperature in the respiratory tract. Takahashi et al [1999] have researched the relationship between thermal tolerance limits for breathable air against dry bulb, wet bulb temperature and ventilation rate. The maximum tolerable temperatures for air varying between <20% RH and saturated air, together with the influence of ventilation rate on maximum tolerable wet bulb temperature are shown in **Figure 2.3** and **Figure 2.4**. Takahashi et al [1999] suggest that, at least up to 90°C, dry bulb temperature has little effect on heat perception and that the maximum breathable temperature is not influenced to a practical extent by breathing rate.

This work also examined how much heat is gained by the respiratory tract from hot humid air at the limit of tolerance. Assuming an isobaric heat transfer process, and using measurements of inspired and exhaled air temperature, it has been possible to determine experimentally the heat gain. It has been shown that heat transfer from hot, saturated air at the limit of tolerability (up to ~9 kJ/min heat gain) would be a significant fraction of the work joules associated with steady walking (where work joules is a measure of the additional energy consumption over and above the basal or resting metabolic rate). It is conjectured that the additional heat burden from a respiratory protective device may reduce the net effectiveness of subjects' efforts to deliberately restrict their walking pace to reduce thermal stress in extreme climatic conditions.

Based on communications with Health and Safety Laboratory, Sheffield and other specialists, and with reference to respiratory protective device testing standards for both personal protective equipment and escape devices, there was agreement for a limit figure of 48-50°C, where the air is saturated or close to saturated. The maximum inspired air temperature within RPD test standards is anticipated to include a margin of safety. The temperature limit in some standards is also a function of wearing time. Example standards include US Code of Federal Regulations, Title 42, Part 84, 103(c), which permits a maximum allowable temperature for inspired air of 62°C at 15 minutes wearing time, to 46°C at 4 hours wearing time for escape only devices. UK standard BS EN404:1993 (s 5.16.3), for filter self-rescuer escape devices, identifies an inhalation air temperature limit of 90°C dry bulb and 50°C wet bulb during the minimum test duration.

The discussion on inspired air safety is continued in Part B, subsection 4, where the use of alkali based CO_2 absorbents in anaesthesia and air purification systems is reviewed.

B: DEVELOPMENT OF HOT INSPIRED AIR SIMULATORS

This section has been structured as follows:

1. Background data pertaining to W95 FSR thermal behaviour.
2. Hot air simulator using air-liquid heat exchangers.
3. Hot air simulation using chemical reagents - choice of reagent.
4. Experience of using soda lime as a respiratory carbon dioxide absorbent.
5. Description of MSA hot air training model.
6. Modification of MSA hot air training model - refillable canister.
7. Reactive plastic cartridge (RPC) CO_2 absorbent technology.
8. SCSR hot air training simulation options.
9. General comment on options for a mining industry hot air training model.

1. Simulation of the W95 FSR - Background Data

In gauging the design of a hot air filter self rescuer simulation unit, it was considered necessary to model, as far as practicable, the breathing characteristics and heat burden imposed by the W95 FSR. Specifications for the MSA-Auer W95 are summarised as follows:

Weight (with container):	0.9 kg
Weight (without container):	0.52 kg
Dimensions:	14cm H, 10.2 cm W, 8.5cm H

Duration: > 240 min
(40 l/min, 0.25 %vol CO, 27g/m^3 absolute humidity (≡28°C fully saturated)
CO penetration max. < 200 ppm)

Breathing resistance:	@ 125 l/min
Inhalation (start):	<4.5 mbar
Inhalation (end):	<5.0 mbar
Exhalation:	<2.3 mbar

Inhalation temperature: <80°C
(conditions as per duration test but with 1.5 %vol CO)

A cross sectional diagram showing the detail of the W95 is given in **Figure 2.5**. Inhalation temperature data was also checked regarding the findings reported by British Coal Corporation in the ECSC final research report concerning the underlying development work of the monolithic catalyst used within the filter self-rescuer [Orr, 1993]. The tests conducted by British Coal included measurement of the maximum inspired air temperature at various challenge concentrations of carbon monoxide. The results are reproduced below:

CO challenge concentration	Maximum inspired air temperature, °C	Maximum inspired wet bulb temperature, °C	Relative humidity of inspired air, % measured	(Relative humidity of inspired air, % calculated)
500ppm	33.1	26.0	58	(55.2)
1000ppm	34.0	26.0	55	(51.1)
0.25%	38.0	27.5	45	(42.7)
0.75%	49.8	35.0	38	(36.2)
1.5%	60.9	39.0	30	(25.1)

Source: Orr, 1993

The upper limit of 1.5% was chosen since experience in the analysis of mine atmospheres indicates that at this concentration of CO, the level of oxygen present would be below that required to support life. The maximum inspired air temperature of 61°C is contrasted with 85-90°C expected from the older 290 design of FSR under similar test conditions. These tests were nominally carried out at 30 l/min minute volume breathing rate. At higher breathing rates, the maximum inspired air temperature would increase, particularly at high challenge CO concentrations.

For comparison, brief information is given on the SSR30/100 chemical oxygen self rescuer unit, with the breathing circuit shown diagrammatically in **Figure 2.6**.

Weight (with container): ~2kg
Dimensions: 18cm H, 18cm W, 10cm D

Breathing resistance: 3 - 7 mbar
(inhalation and exhalation)

Oxygen content: 21 %vol.

2. <u>Hot air simulation using air-liquid heat exchanger</u>

Whilst a chemical absorbent can provide a small, compact air-preheating device, there are inherent disadvantages with this approach. These include:

- Limited heating duration associated with a small volume of absorbent.
- Limited control over the inspired air temperature.
- Relatively high exhalation breathing resistance.

An alternative approach to hot air simulation systems was to employ an air-liquid heat exchanger. This approach is advocated where a controlled range of inspired air temperatures and humidity is required, particularly in a laboratory setting. However, an air-liquid heat exchanger preheating scheme is a static system, and mobility is restricted to that provided by the umbilical air breathing hose.

In order to investigate the range of inspired air temperatures available, an appropriate high-efficiency thin-walled stainless-steel heat exchanger was obtained (**Figure 2.7**). This incorporated a controlled source of hot water (working fluid), a closed circuit reservoir, thermostatically heated with delivery to the heat exchanger regulated by a simple variable pump and gate valve arrangement. The flow circuit is shown in **Figure 2.8**.

As an essential safety feature, all development work was undertaken with a breathing machine, as shown in **Figure 2.9**. This permitted a wide range of circulating hot water temperatures, pump pressures and flow rates to be examined without concern of inspired air temperature exceedence. This approach also obviated the need for a water trap to be installed in the breathing circuit (in case of catastrophic failure of the heat exchanger).

At typical breathing rates, a significant heat loss was observed through the umbilical air hose. The initial response to this was to incorporate thermal insulation around the air hose. With this experimental arrangement in place, inhalation temperatures in excess of 50°C could be obtained. As a further development, it would be beneficial to sense the inspired air temperature close to the mouthpiece and incorporate this within a closed loop controlled configuration. By this means, it would be possible to compensate for wide variations in breathing rate and heat loss through the umbilical air hose.

3. Use of chemical reagents for a hot air simulation unit

The general principle of a chemical hot air unit is to exploit the exothermic heat of neutralisation associated with absorption of carbon dioxide in the exhaled air stream. The reagent, if tightly packed in granular form, acts as a recuperative heat exchanger, heating the inhaled air stream to temperatures of 50°C or more.

The choice of a chemical reagent within a hot air training unit was examined. Essentially, the absorption of carbon dioxide involves the neutralisation of an intermediary product, carbonic acid, with an appropriate alkali base. The absorbent chemicals available include:

- Sodium hydroxide and potassium hydroxide.
- Superoxides of potassium and sodium.
- Lithium hydroxide.
- Barium lime.
- Soda lime.

Consideration of material toxicity and corrosivity characteristics, indicated that soda lime and possibly barium lime were most suitable for use in a unit that has close proximity to the oral and respiratory tract. The associated absorption reactions for both reagents are as follows:

CO_2 absorption involving soda lime:

$$H_2O + CO_2 \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$
$$NaOH + H_2CO_3 \longleftrightarrow NaHCO_3 + H_2O$$
$$2NaHCO_3 + Ca(OH)_2 \longleftrightarrow 2NaOH + CaCO_3 + H_2O$$

The primary constituents of soda lime include calcium hydroxide - $Ca(OH)_2$ (about 70-80%), water - H_2O (about 16 to 20%), sodium hydroxide - NaOH (about 1-2%), and potassium hydroxide - KOH (about >0-1%). Water is an important part of the reaction which takes place to bind the CO_2. The general description of the reaction is as follows. Firstly, the gaseous CO_2 reacts with water to form carbonic acid - H_2CO_3. Then, the NaOH reacts with the carbonic acid to produce Na_2CO_2 and H_2O. The Na_2CO_2 reacts with the $Ca(OH)_2$ which has been dissociated into calcium and hydroxide ions (Ca++ and OH-) to produce $CaCO_3$ (calcium carbonate). The CO_2 is now in a relatively stable state. There is a nett production of three H_2O molecules for every molecule of CO_2 absorbed together with exothermic heat. The complete reaction is still not fully understood.

CO_2 absorption involving baralyme:

$$Ba(OH)_2 \text{ and } 8H_2O + CO_2 \text{<------->} BaCO_3 + 9H_2O + \text{heat}$$
$$9H_2O + 9CO_2 \text{<------>} 9H_2CO_3$$
$$9H_2CO_3 + 9Ca(OH)_2 \text{<------>} 9CaCO_3 + 18H_2O + \text{heat}$$

Barium hydroxide and water combine with carbon dioxide to form barium carbonate, water, and heat. Water and carbon dioxide form carbonic acid. Carbonic acid and calcium hydroxide form calcium carbonate, water, and heat.

Typically during respiration, 0.82 litre of CO_2 is exhaled per litre of oxygen inhaled. The reagent chemistry indicates that 0.116 kg soda lime can absorb one mole of carbon dioxide (22.4 l @ STP). However, because of the channelling of expired gases through the canister, only 10 to 20 litres of CO_2 are absorbed in practice per 100 grams of reagent. The efficiency of CO_2 absorption is inversely proportional to the hardness of the soda lime. Hence the addition of silicates to prevent powdering is a compromise. Granule size and morphology are also important. Small size increases absorbent area but increases resistance to gas flow. To increase effective surface area for absorption, the granules are made porous and irregular in shape. The sieve sizes of 'Sofnolime', a commercial soda lime absorbent product made by Molecular Products Limited, Thaxted, UK are shown in **Figure 2.10**.

In terms of heat of neutralisation in the canister, there is no direct correlation between heat production and remaining absorbent capacity. The exothermic absorption of one mole (40g) of CO_2 generates one mole of H_2O and 57kJ of heat energy [Wissing and Kuhn, 1998].

4. Use of soda lime as a respiratory CO_2 absorbent

There is a significant application base for alkali based CO_2 absorbents, including:

- Low flow anaesthesia.
- Closed circuit breathing apparatus (mining and diving).
- Submersible vehicle air purification.

Of particular relevance is the experience of using soda lime in clinical settings, mainly for anaesthesia, but also for field treatment of hypothermia. This has provided a wide range of references on absorbent behaviour and breathing circuit humidification requirements and any associated respiratory hazards. A brief review is provided here.

Dosed or almost dosed anaesthesia systems have been in use since c1850. At that time, the anaesthetic agent was chloroform, administered via a dosed system, with potassium hydroxide utilised as a carbon dioxide scavenger. The first soda lime carbon dioxide absorbent canister was introduced to anaesthesia in 1917. The introduction of low solubility anaesthetic agents has increased the use of low flow anaesthesia, and there is a significant body of knowledge on the application of soda lime and baralyme as carbon dioxide absorbents [Baum et al 1993, Freys 1999, Gootjes and Lagerweij 1981, Juniot et al 1999, Murray et al 1999]. In this type of application, 0.5 kg of soda lime will typically last for 6-8 hours.

In order to prevent dehydration damage to the respiratory tract and to maintain the function of the tracheobronchial epithelium, a water content of at least 15-20 mg H_2O/litre inspired air is advised in long-term anaesthesia [Ingelstedt 1956, Kleeman 1994]. The application of a heated, humidified air as a primary or adjunct treatment for hypothermia is well established. For field treatment of casualties, a variety of devices have been developed which exploit the heat of neutralisation from carbon dioxide absorption [Collis et al 1977, Hayward and Steinmen 1975, Lloyd 1990, Lloyd 1991].

The core organs, which constitute approximately 8% of the total body weight, contribute 56% of the heat production in basal metabolism at normothermia. Rewarming methods thus concentrate on delivering heat to the body core organs, with air rewarming being a relatively safe, effective method. Complete humidification of the inspired airstream is however necessary for maximal heat delivery [Goldberg et al 1992, Linning et al 1986]. A rewarming rate of 1 to 2.5 °C per hour is observed, depending on the delivery technique, with an endotracheal tube being more rapid than a mask. In order to prevent damage to the pharynx, the maximum temperature of the inspired air is maintained at between 42°C to 45°C.

Within the above-cited references, it is clear that soda lime absorbents can, with appropriate design controls, be used to directly heat the inspired air stream. A soda lime absorbent canister was used in the climate chamber trials to simulate the hot air effects from an FSR operating in a high CO challenge atmosphere.

5. MSA hot air training model self rescuer

Approximately a decade ago, MSA manufactured a hot air training model self-rescuer. This device is no longer available and the manufacturer has indicated that it does not anticipate future involvement in the manufacture or supply of hot air training self rescuers. The design was examined for consideration as the basis of a unit for the climate chamber trials.

The MSA device is well engineered, employing a purpose-designed reusable mouthpiece assembly into which the reagent canister is bayonet-fitted prior to hot air training being conducted. The reagent canister was intended to be a disposable unit, and was supplied pre-packed with reagents, ready to use in a hermetically sealed foil bag. The various components are shown in **Figure 2.11**.

The MSA canisters contained approximately 120g of 1.0 - 2.5 mm particle size soda lime (Sofnolime or equivalent) together with 50g of a solid absorbent desiccant. The reagent canister design has a fine woven mesh screen inserted between the reagent layers, and a plug of HEPA material adjacent to the mouthpiece in order to prevent dust arising from mechanical attrition of the reagent being inhaled.

The units were physically modelled on the 275 type rescuer and had a nett weight of 525g (cf 625g for the actual 275 type rescuer). A cross-sectional diagram of the assembled hot air training model is given in **Figure 2.12**. It is noted that the exhalation valve is sealed and is non-operational. In order to prevent the possibility of interchange with operational type valves, a different thread is used for attachment to the plastic mouthpiece.

Without access to the original design data, the specifics of thermal behaviour, breathing resistance and reagent choice can only be speculated. The solid desiccant adsorbent is not considered likely to have a significant operational role (i.e. airstream dehumidification), but rather, has a role in inhibiting corrosion of the pressed steel canister over the shelf-life of the unit. General classes of solid adsorbent dessicant include; silica gels, zeolites, synthetic zeolites (molecular sieves), activated aluminas, carbons and synthetic polymers [ASHRAE 2001]. Sorption isotherms for various desiccants are given in **Figure 2.13** for reference [ASHRAE 2001].

The National Coal Board specified training sessions with the MSA hot air rescuer incorporated optional exercise, but were limited to a total wearing time of 15 minutes. The units could also be fitted with temperature sensitive indicator tape (spot temperatures >40, 43, 46, 49, 54, 60, 65, 71, 77 and 82 C) to record the peak temperature of the canister in use.

6. Adaptation of the MSA hot air training model

A limited number of mouthpieces and sealed reagent canisters were obtained from within MRSL. The reagent canisters all had a use expiry date of circa 1991. A number of sealed units were opened which confirmed that whilst many of the canisters were probably still serviceable, around 15 - 20% showed evidence of significant internal corrosion and were not usable. Given that it was essential to provide consistent performance in the hot air training models used within the chamber trials, it was considered necessary to adapt the MSA design for use.

The changes to the MSA design were relatively minor. Firstly, the desiccant was dispensed with and the entire canister filled with soda lime. This was to extend its operating life. To provide a lower breathing resistance, a larger sieve size of Sofnolime (2.5 –5.0mm) was used. Again, to prevent particulate carry over into the lungs, the air filtration medium was retained in each canister. Significant corrosion of the pressed steel canister took place, and hence filling was undertaken shortly before each trial. The extent of the corrosion can be gauged from **Figure 2.11**, with a new canister shown inset.

Tests of inspired air temperature were conducted of the modified design under the following circumstances:

1. Treadmill walking at 37 °C, 100% humidity, 3 km/hr average speed.
2. Treadmill walking at 28 °C , 100% humidity, 3.5 km/hr average speed.
3. Treadmill walking at 20 °C, 50% humidity, 4 km/hr average speed.

The first of these tests was to establish the maximum possible temperature obtainable from the device at very high ambient temperatures with saturated air. In this case, maximum inspired air temperatures were ~50°C. The temperatures were measured by an invasive temperature probe, inserted into the centre of the airstream within the mouthpiece.

Tests 2 and 3 above were conducted to establish what heat burden could be asserted at lower environmental temperatures. Results showing the temperature rise characteristic are given in **Figure 2.14**. Under the specified conditions, peak temperatures of 46 °C were recorded. **As an observation, the soda lime hot air training model used in the trials achieved a relatively low peak temperature, which could only be sustained for a relatively short time, circa 10 minutes. This device may not be representative of a filter self-rescuer worn in a high CO concentration atmosphere for extended periods.** The duration of the hot air effect is dependent on the mass of the reagent. With a larger canister design, peak temperatures could be maintained for a longer period. Against this, the additional size and weight could impose significant discomfort on the wearer.

Excluding experimental test wearings, data was collected for 18 test runs involving hot air, filter self rescuer units. The subjects were debriefed to ascertain their views on the tolerability of wearing the hot air units. All subjects indicated that the units produced air, which was hot but not unbearable. For some individuals, the principal difficulty was the high breathing resistance associated with the device after about 10 to 15 minutes of wearing. On investigation, it was concluded that the additional breathing resistance was almost entirely arising from saliva building up in the air filter material adjacent to the mouthpiece. In spite of the higher breathing resistance observed for the device after a period use, it was considered essential to preserve the air filtration as a safety feature, and no changes were made in this regard.

7. Reactive plastic cartridges

One new technology considered to have possible application in a hot air training unit is the "reactive plastic cartridge (RPC)", manufactured by Micropore Inc., USA.

These cartridges eliminate the channelling and performance variability inherent in granular systems, by binding the CO_2 absorbent within a microporous sheet material with factory-moulded channels. The sheet is then spiral wound to form cylinders of arbitrary length and diameter. This approach offers a drop-in cartridge replacement capability with precise control over breathing resistance, absorbent utilisation and hence minimum duration. Typically, an RPC technology has a mean duration repeatability of $\pm 5\%$ within two standard deviations. Granular system variability in duration is typically no better than $\pm 30\%$.

RPC based CO_2 scrubbers have the lightest weight and smallest size for a given scrubber duration. Absorbent reagent carry over into the exhaust airstream is also reduced. Physical details are given in **Figure 2.15**. The graph shows the amount of CO_2 in a closed circuit breathing loop after being passed through a conventional granular canister and an equivalent RPC canister (the shaded areas represent three standard deviations around the mean performance).

One engineering issue in the use of RPC technology is in ensuring an even flow distribution across the face of the cartridge. This can be accomplished by installation of a diffusion screen or air filter. In a practical hot air training unit, the air filter material inserted prior to the mouthpiece would achieve this function.

Further research could include modelling and optimising the recuperative heat exchange behaviour and breathing resistance of the cartridge. The ability to manufacture cartridges of arbitrary aspect ratio would be of assistance in any empirical refinement process.

8. SCSR training simulation

The inherently high cost of self contained, self rescuer escape apparatus, particularly long duration models, discourages their use in training programmes. Some mining industries, such as the remaining French coal mines, use the SCSRs withdrawn at the end of their five-year service life for training purposes. This approach provides first-hand experience of SCSR initiation and breathing characteristics, but is only appropriate to a rolling programme of hot air wearing experience of SCSRs. The diversity of SCSR designs in use within the mining industry also means the wearing experience and training may not necessarily reflect the apparatus carried underground.

An alternative approach is to use a purpose-designed SCSR simulator at centrally or regionally located training facilities. This latter approach reflects the statutory training provisions in the mining industry of Asturias, Northern Spain. Summary details of the training approach and the simulator system developed are given here.

The mine workforce in Asturias is estimated at 6000-7000. Three principal types of SCSR are employed; Dräger Oxyboks, MSA SSR 30, and Fenzy Biocell 1. A limited number of underground incidents have occurred where individuals had some difficulty in donning and using their SCSR effectively. Consequently, a decision was made by the Spanish authorities to provide all mineworkers with a realistic simulated experience of wearing an SCSR under various exercise conditions.

A study was undertaken by the Institute of Silicosis, Oviedo on the breathing characteristics of SCSRs whilst exercising within a range of representative treadmill gradients and speeds. This work was a precursor to the development of a purpose-designed SCSR simulator. The simulator is designed to provide a realistic experience and appreciation of temperature, humidity and breathing resistance effects. Essentially, the simulator employs a computer-cycled treadmill and SCSR mouthpiece assembly supplied with air of controlled humidity and temperature. The breathing resistance is also maintained under closed loop control.

The system provides wearing experience in two phases; a hot and humid phase, and, a hot, dry air phase. A variety of submaximal test exercises can be set up on the treadmill. Typical maximum parameter values reached during the tests are as follows:

Breathing resistance, symmetrical:	6-8 mbar
Humidity:	75-80% at 55°C
Treadmill:	8% gradient, 4-5 km/hr
Hot air period:	5 minutes (Phase 1) + 4 minutes (Phase 2)

Figure 2.16 and **Figure 2.17** provide views of the Spanish simulator operator's console and internal engineering detail respectively.

At the end of 2000, approximately 2000 employees had been trained using the simulator, with 12 trainings per day capacity. Feedback from staff who have worn SCSRs, confirms that the simulation is challenging and realistic.

9. Options for a mining industry hot air training model

Statutory Instruments, 1995, Number 2870, Health and Safety, *The Escape and Rescue from Mines Regulations, 1995*, Regulation 10, 'Arrangements for Escape', prescribes a duty on the owner of every mine to provide suitable self rescuers for all persons going below ground. Within the same Regulation, ACOP 56-64 make reference to the training requirement. In particular, ACOP 56 states:

> *"both initial and refresher training will need to include the option of hot air experience"*

Appendix 4 relating to self-rescuer training in the same Regulations provides further guidance:

> *"**Hot air experience***
>
> *Where filter respirator self-rescuers are provided, trainees should have an opportunity to experience breathing hot air by wearing a hot air training model of the self-rescuer for about 15 minutes or by an extended wearing of a normal self-rescuer resultingin an increase of temperature and resistance. The aim of this experience is to simulate the breathign conditions that would exist when wearing a self-rescuer in real emergency conditions underground. Training should conclude with a summary of the main training points and a check of the trainees' understanding."*

Participation in such training has never been mandated, and arguably, this has resulted in lack of commercial incentives to develop hot air training models or simulators. With the use of filter type self rescuers now limited essentially to the UK and Germany within Europe, there is probably an insufficient market size to justify commercial development programmes.

If industry is to be provided with hot air self-rescuer training, it will require development of one or more of the following options:

1. A redesign of the MSA hot air training unit to incorporate a refillable canister design.
2. Development and manufacture of a limited number of simple air-liquid heat exchanger based units.
3. Manufacture of an SCSR simulator, possibly replicating the Institute of Silicosis design (Principality of Asturias, Spain).

In taking the cost of the components of the system into account, it is estimated that an open loop controlled air liquid heat exchanger based hot air simulation system could be assembled at a unit cost estimate of ~£3- 4k. However, various safety features might have to be added and the eventual cost might be somewhat higher, particularly if product development and approval costs must be amortised. The SCSR simulator system is relatively sophisticated and would have a high cost (probably > £50k).

A practical device for use within the mining industry, proposed on the lowest cost approach, may be to have a number of stainless-steel canisters made to the MSA envelope design. Given the modest numbers involved, it would be most appropriate to have these units refillable. The modified design would employ a removable stainless-steel mesh base to permit the units to be filled with dedusted soda lime. No design changes are considered necessary to the proprietary MSA mouthpiece (MSA Part No. 123-0028). Design rights, availability of the MSA mouthpiece part/moulding tools are commercial issues of note here.

As an alternative to hand filling of the canisters, the use of pre-moulded plastic cartridges containing soda lime reagent, so-called 'reactive plastic cartridges', warrants further investigation. Initial discussions were held with Micropore Inc. to define a possible requirement specification. However, again, the market size may be too small to justify manufacture of a purpose-designed product.

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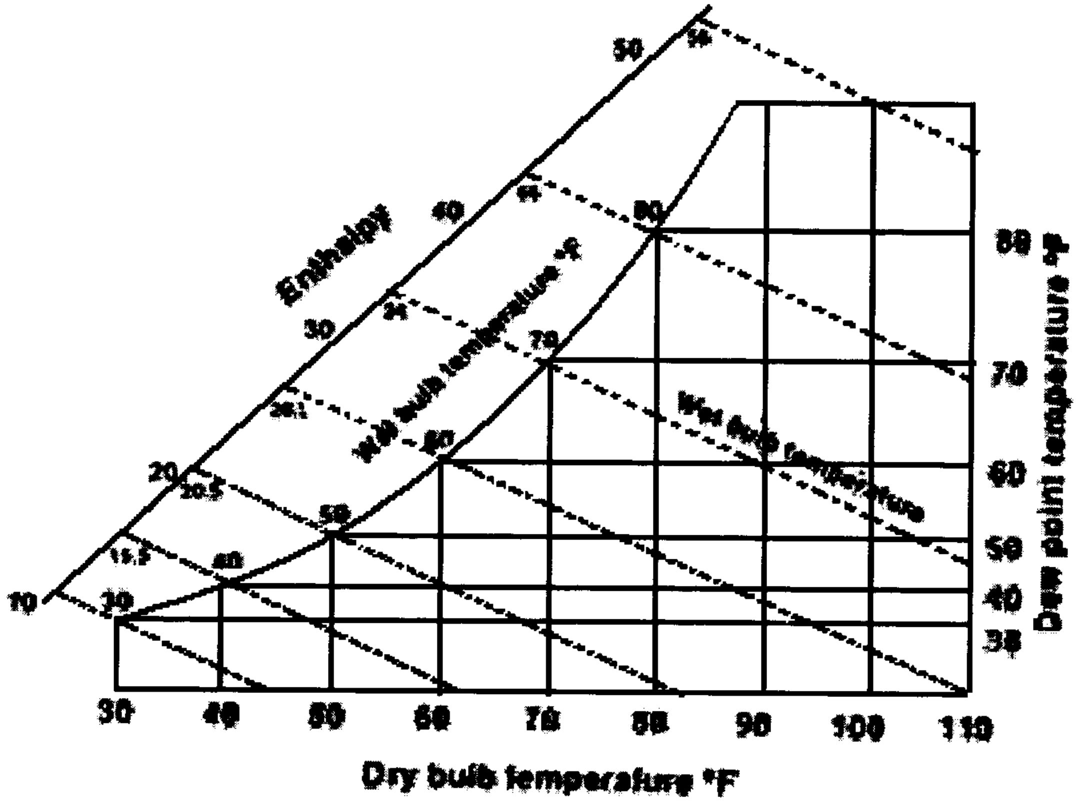

Figure 2.1: Condensed Psychrometric Chart

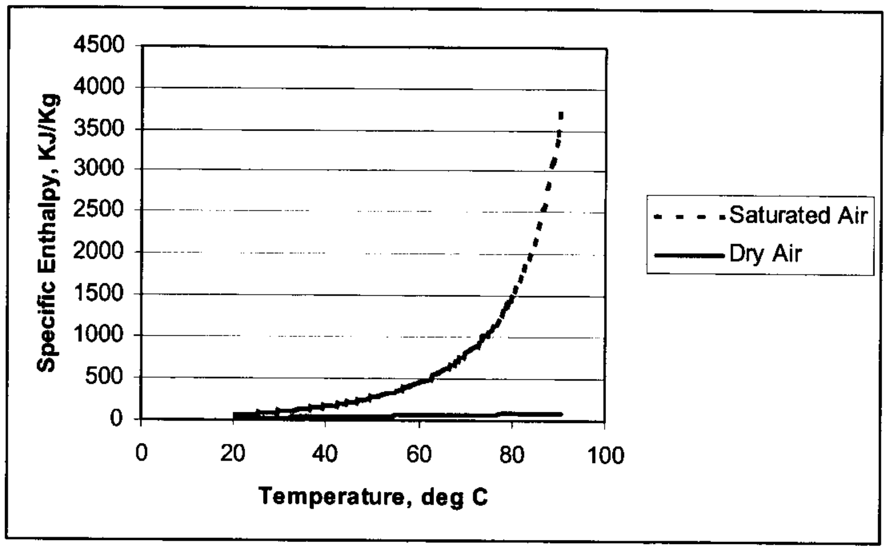

Figure 2.2: Specific Enthalpy Components for Dry and Saturated Air

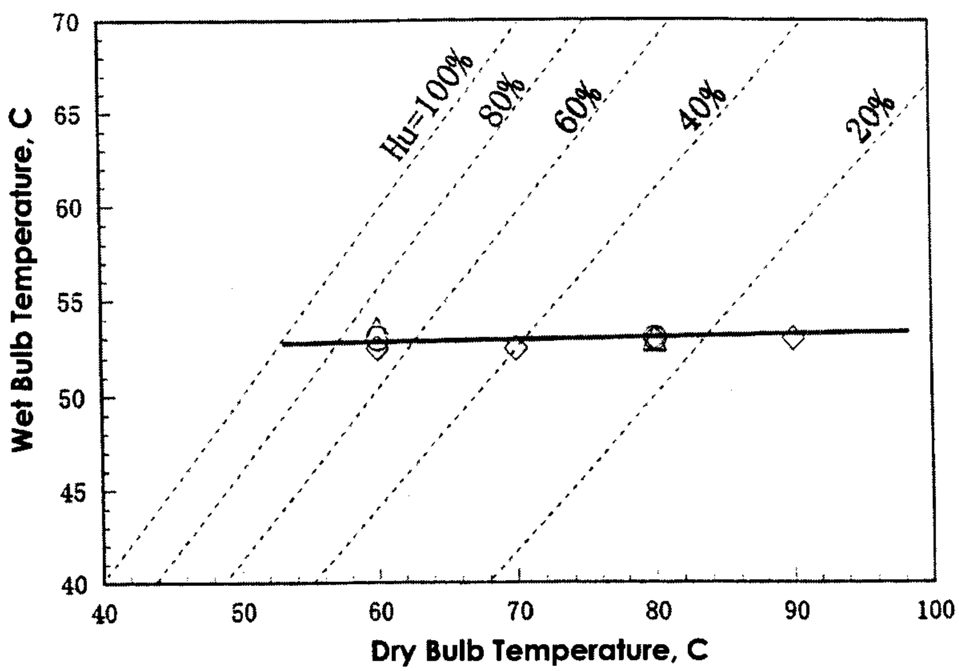

Figure 2.3: Experimentally determined limits of tolerability for various air humidity and temperatures.

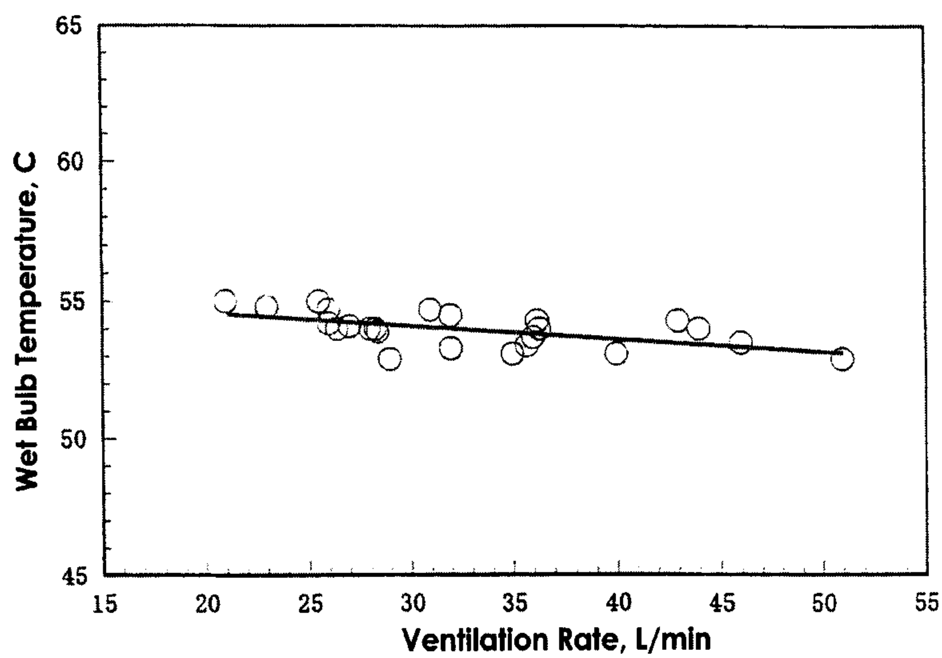

Figure 2.4: Variation of tolerability limits for saturated hot air versus breathing rate.

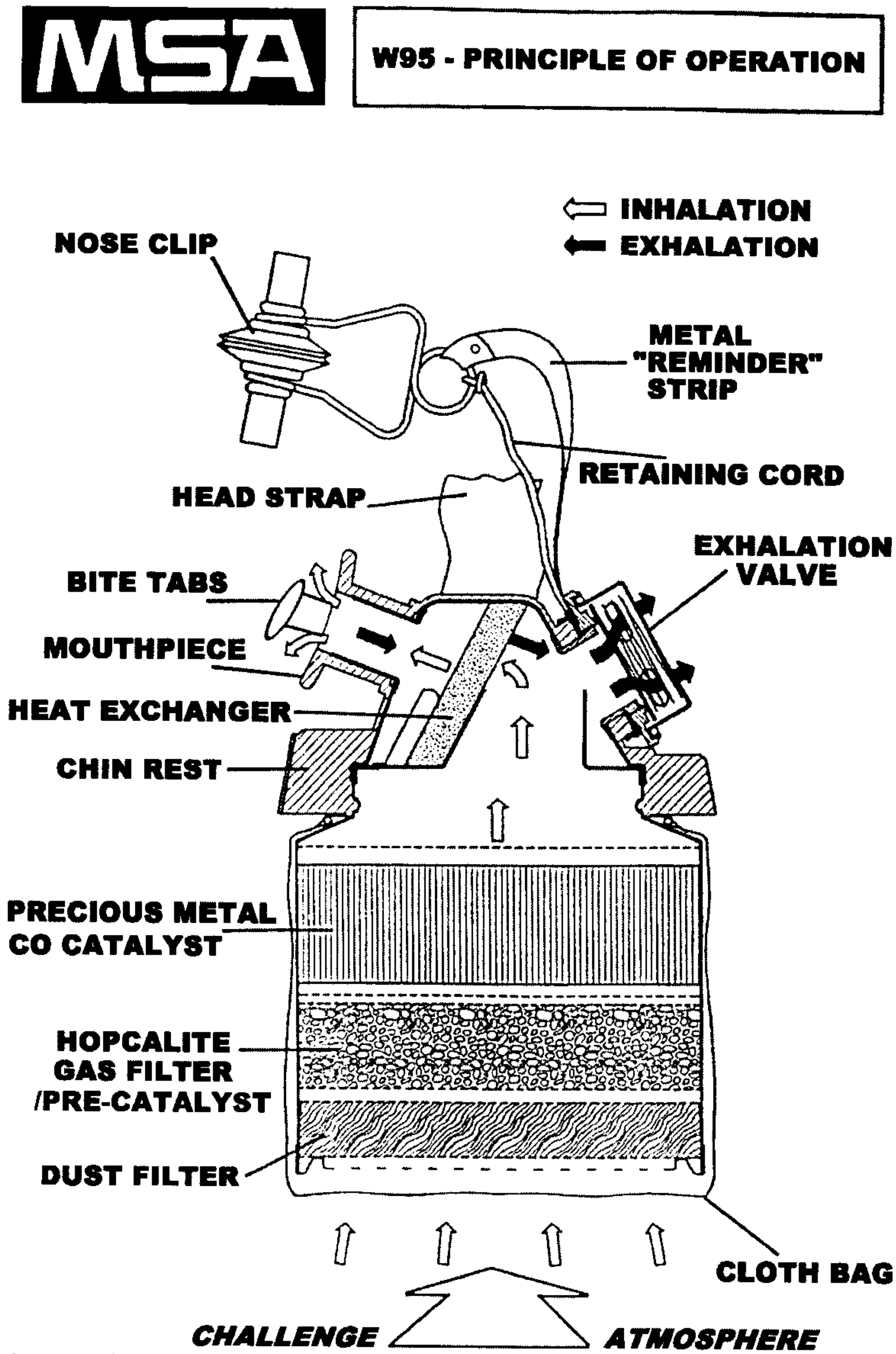

Figure 2.5: MSA W95 Filter Self Rescuer, Cross-sectional View

SSR30 FLOW CIRCUIT

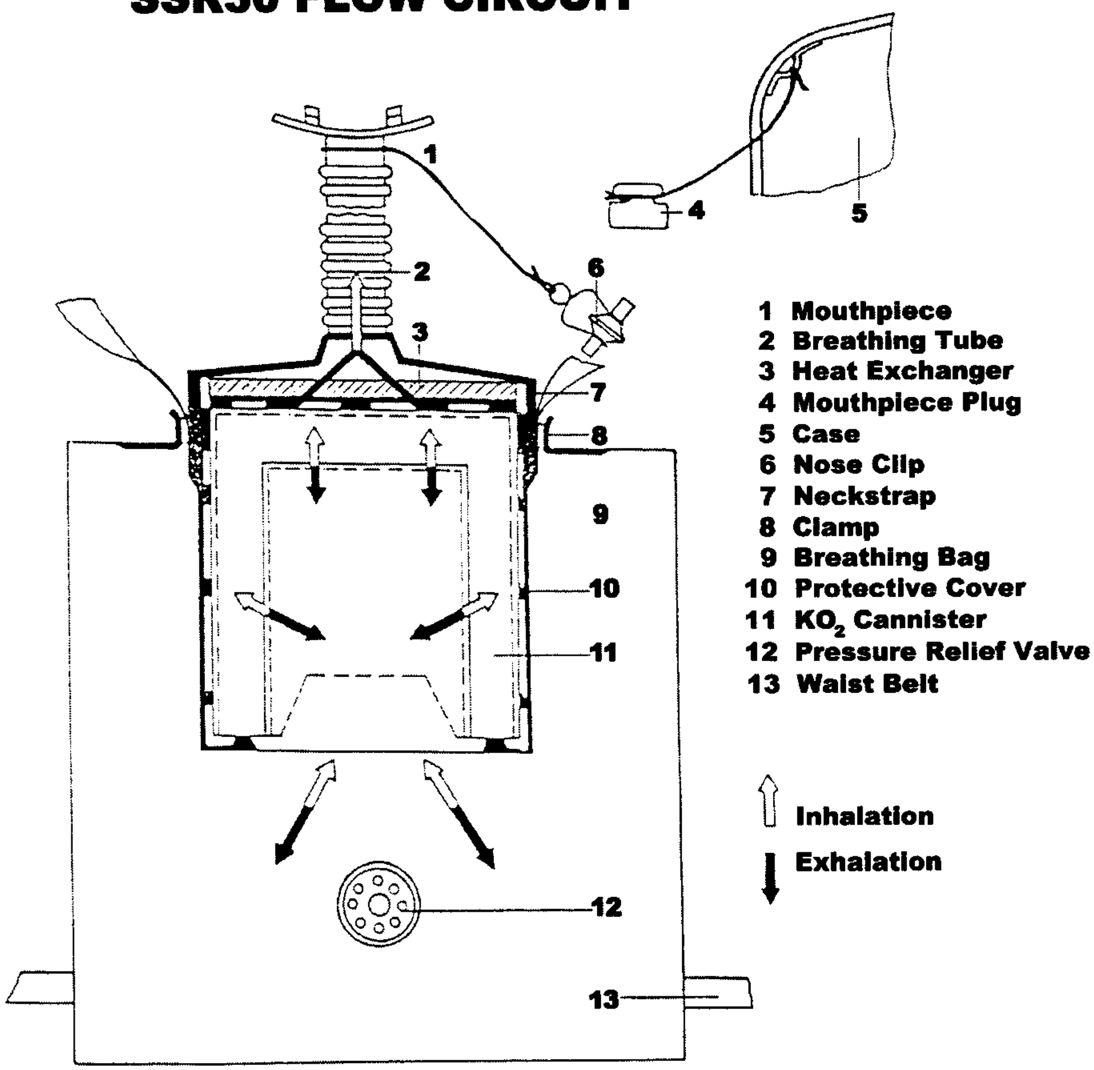

Figure 2.6: MSA SSR30/100 Chemical Oxygen Self Rescuer, Cross-sectional View

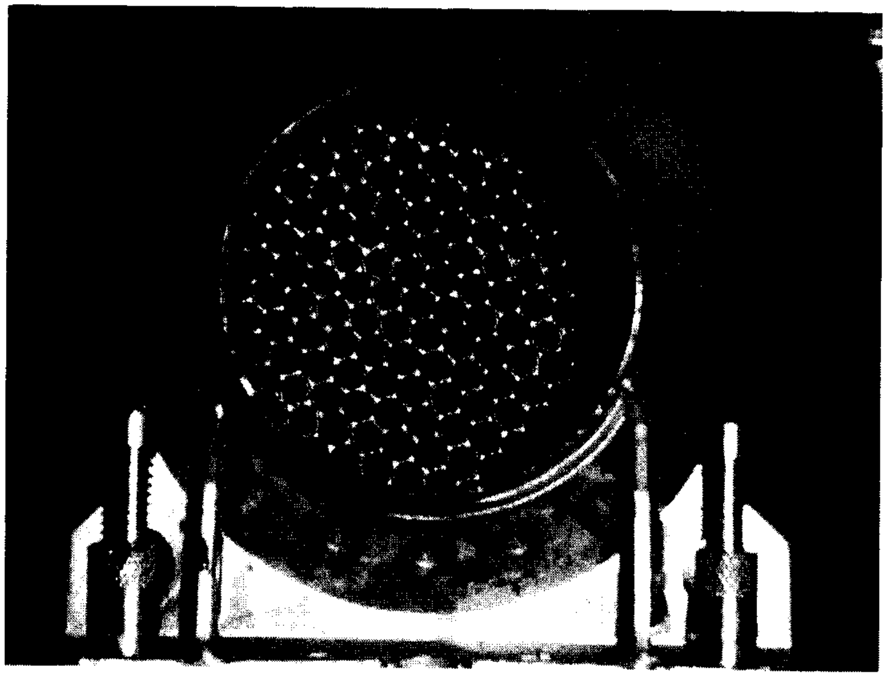

Figure 2.7: Air-Liquid Stainless Steel Heat Exchanger, End View

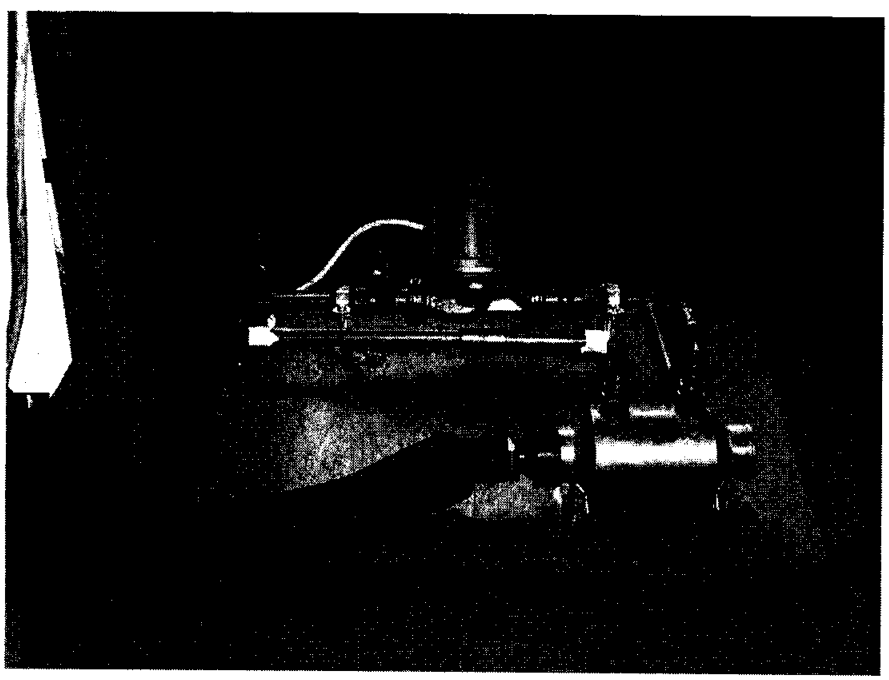

Figure 2.8: Heat Exchanger Flow Circuit

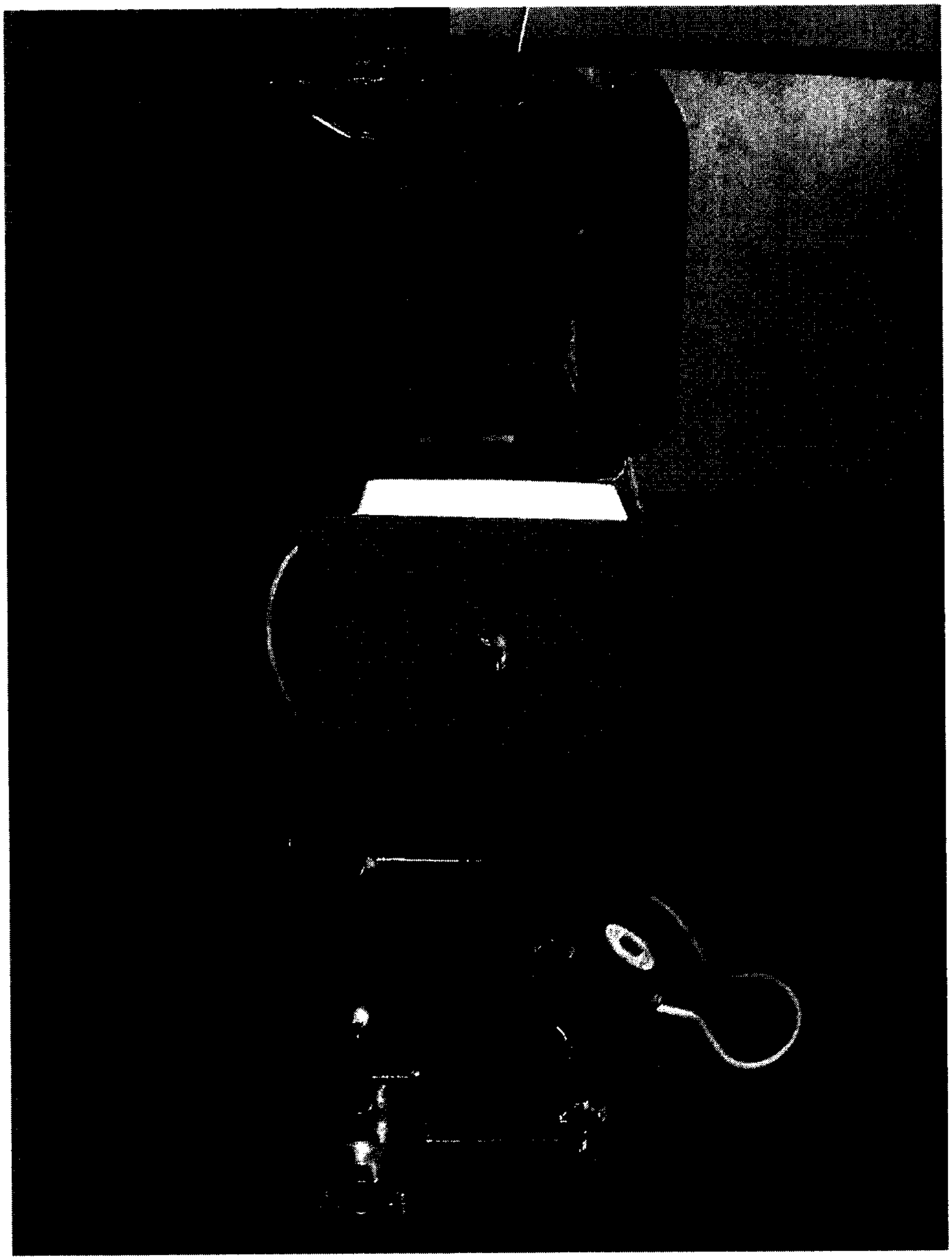

Figure 2.9: Heat Exchanger Flow Circuit and Breathing Machine

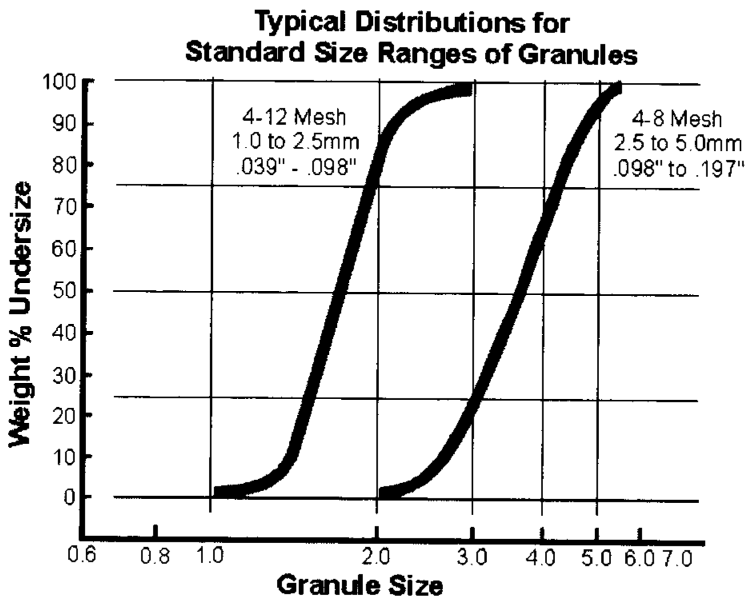

Figure 2.10: Seive Size Characteristics of 'Sofnolime' Soda Lime Product

Figure 2.11: MSA Hot Air Training Unit Components (New canister shown inset)

MSA HOT AIR TRAINING UNIT

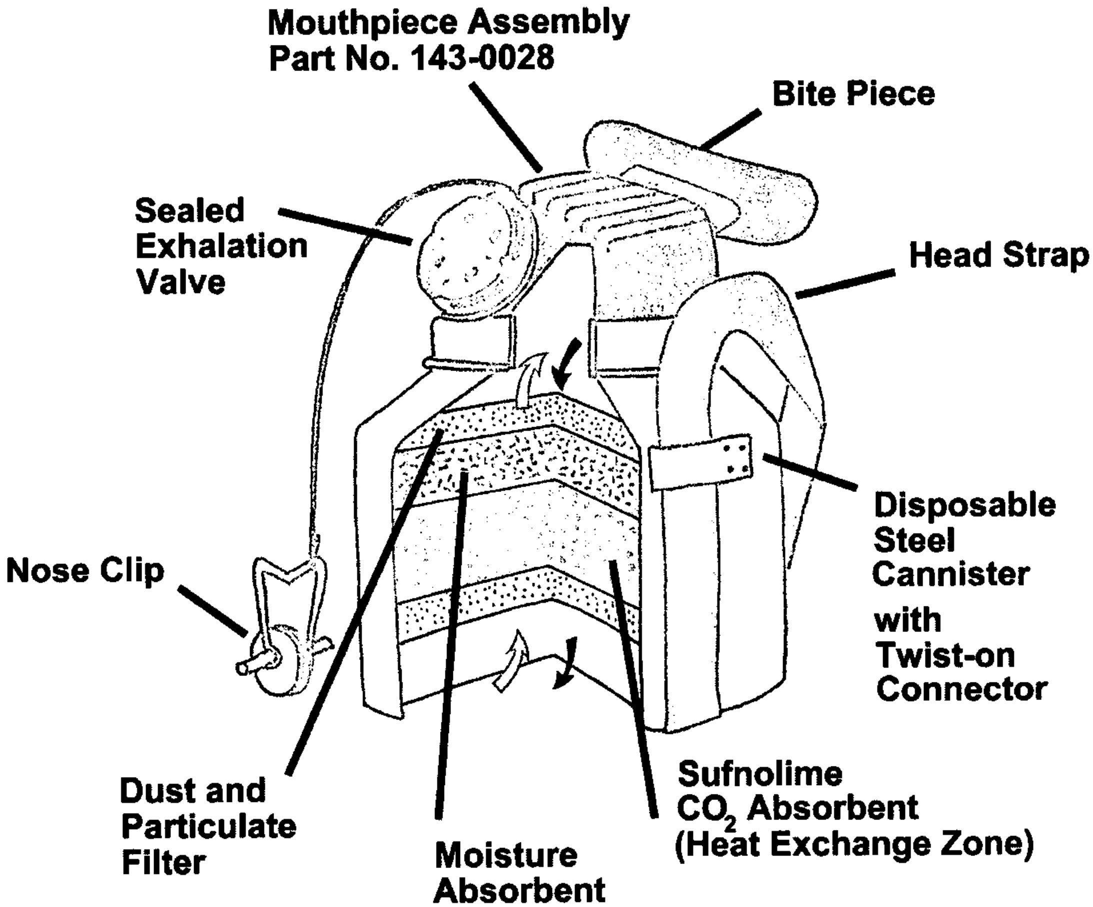

Figure 2.12: MSA Hot Air Training Model, Cross-sectional View

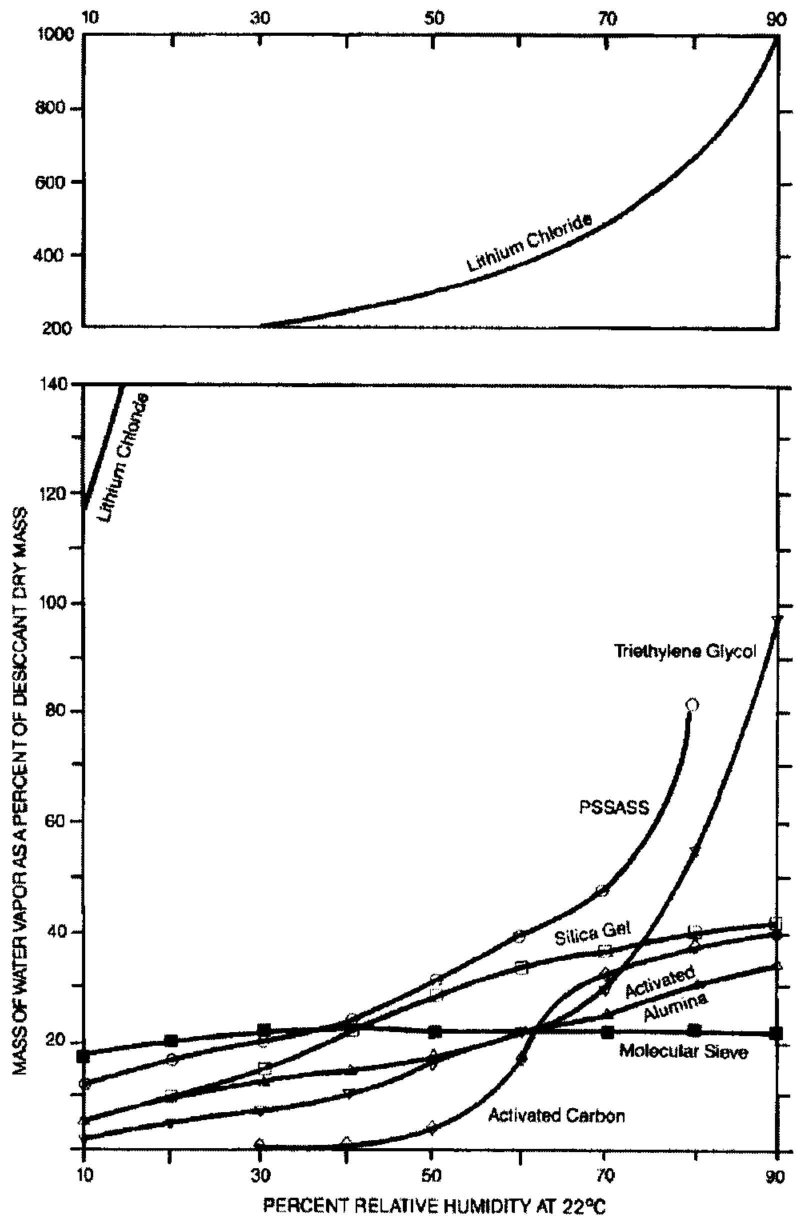

Figure 2.13: Sorption Isotherms for Various Dessicant Types

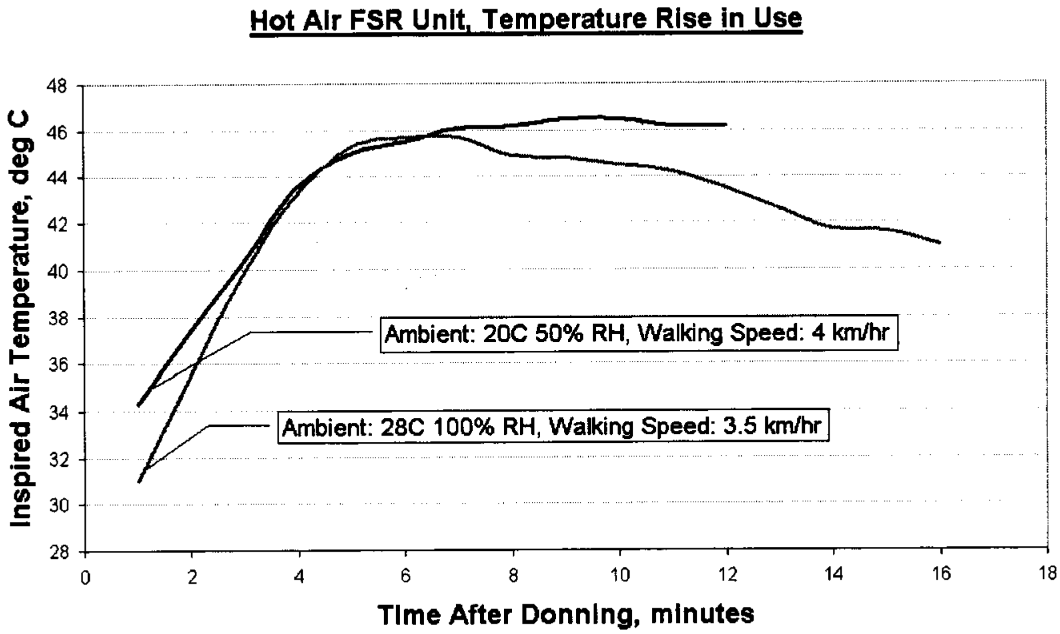

Figure 2.14: Warm-up Characteristics of Modified Hot Air Training Unit

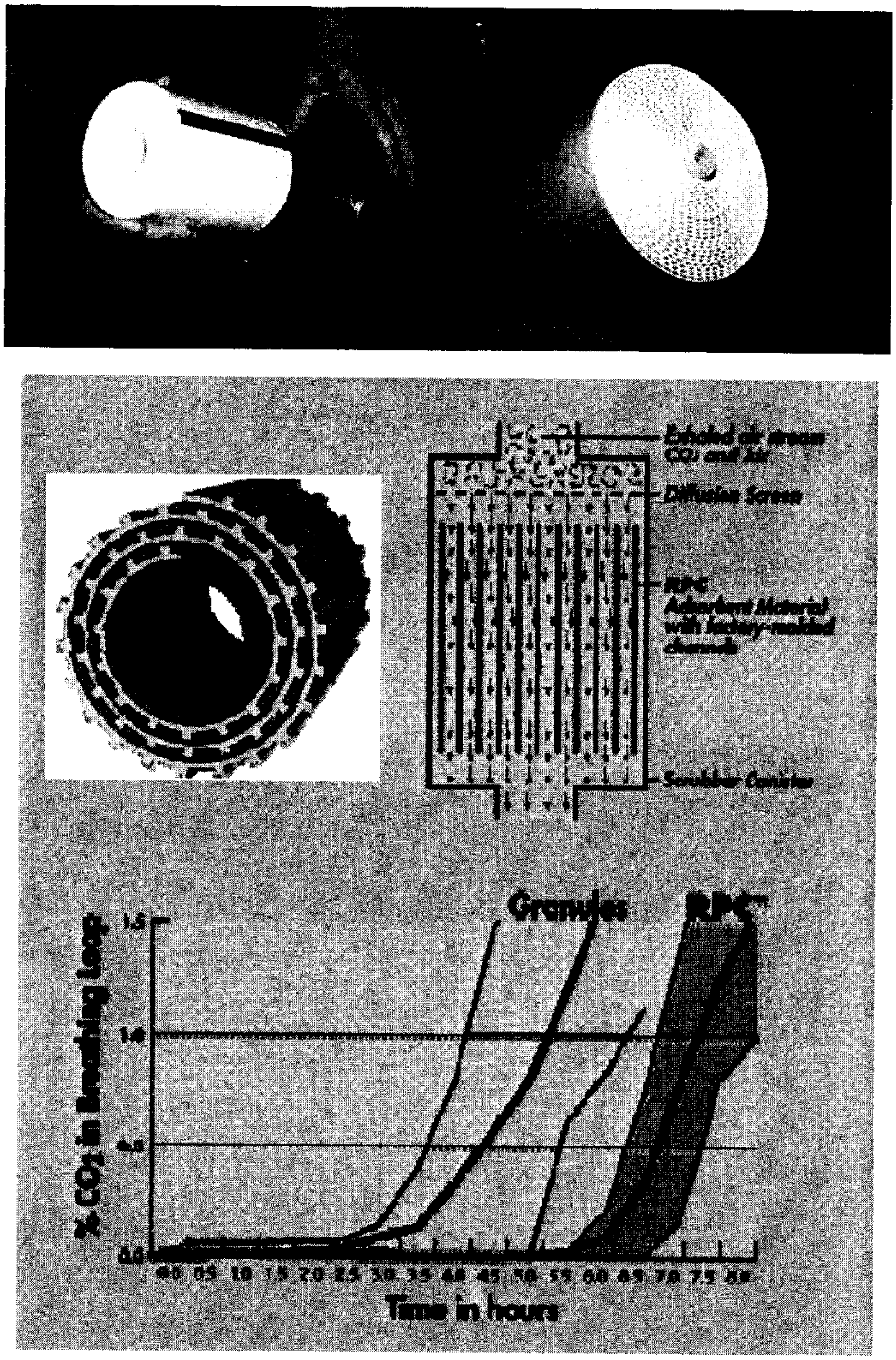

Figure 2.15: Reactive Plastic Cartridge (RPC) Technology, Key Features

Figure 2.16: Institute of Silicosis SCSR Simulator, Operator's Console View

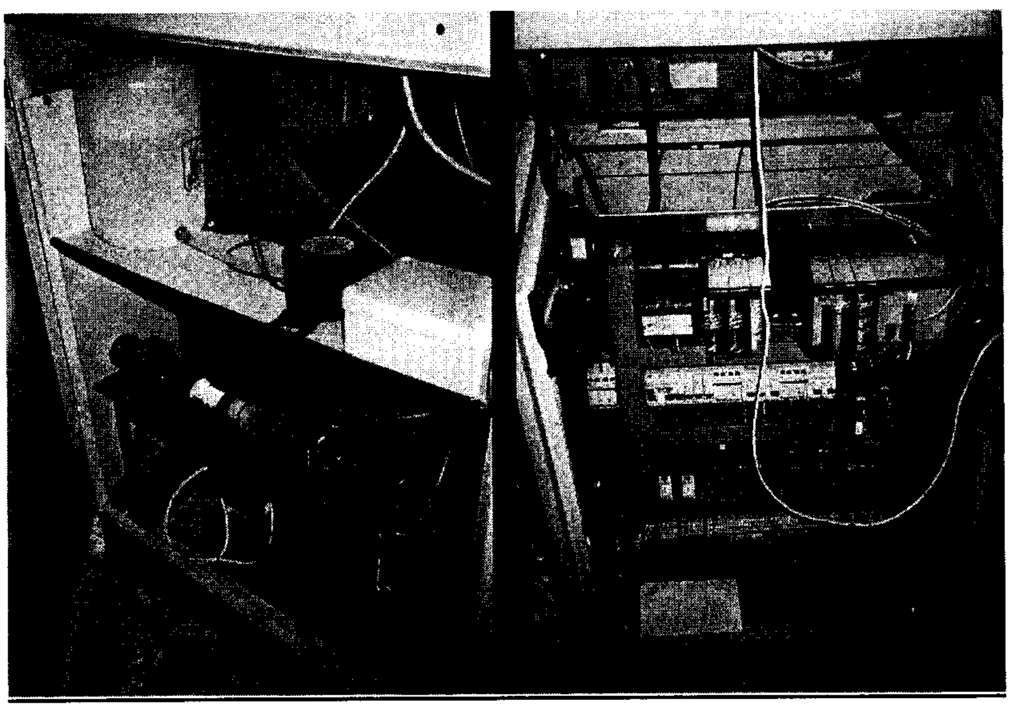

Figure 2.17: Institute of Silicosis SCSR Simulator, Console Internal Detail

SECTION 3
TRIAL DEVELOPMENT ISSUES

There were a number of issues to be considered prior to the implementation of the Climatic Chamber trials in the controlled chamber at the Selby Mines Rescue Station.

- Ensuring the safety and confidentiality objectives of HSE's Research Ethics Committee were fully accounted for.
- Investigating how to simulate the work rate involved in seeking to evacuate a mine and represent mine conditions.
- Examining how best to incorporate these issues within a simple treadmill cycle.
- Accounting for the pre-warming associated with routine work undertaken before an evacuation is initiated.
- Calibration of the treadmills and ensuring the work rate they incur was reasonably representative.
- Review of practice and measurement reliability of physiological monitoring methods.
- Selecting appropriate physiological monitoring instrumentation, which was also suited for use in saturated atmospheres.
- Establishing data telemetry and (outside chamber) real time monitoring facilities for the instrumentation functions.
- As a parallel activity, undertaking an investigation of how to simulate, with appropriate safeguards, the hot air effects of wearing a FSR in a high CO environment.
- Initiating information briefings with test volunteers and selecting subjects.
- Confirming the trial protocol and programming individual test elements therein.

Specific trial development relating to most of these issues are discussed.

1. Trial Hypothesis

Whilst the trials had a number of experimental objectives, there was one specific hypothesis to test:

"In conditions of high heat and humidity, does the wearing of a filter self-rescuer, or the wearing of a self contained oxygen self-rescuer in a mine atmosphere containing a high CO content, have any noticeable effect compared with the baseline reference case, in terms of physiological stress response?"

The test programme involved medically assessed MRSL volunteer staff, each undertaking three wearing trials:

(1) a baseline reference test run without an escape respiratory protective device
(2) a hot air filter self-rescuer training model run
(3) a wearing trial of a representative SCSR (MSA SSR30)

Within this hypothesis, there were a number of experimental influences which needed to be investigated for assessment. Some would be dependent on individual physiological responses, some were environmental variables, and some concerned the possible influence of measurement errors.

In order to arrive at results which had acceptable statistical accuracy, there were recognised benefits in having the test subject group as large as could be practically managed. The overall subject group size was nominally defined to be between 11 and 16 subjects. Furthermore, in order to reduce the number of tests within the programme, and provide for adequate statistical significance, it was decided that the initial baseline reference hot air FSR and SCSR tests, be subject to standard test conditions at a nominal temperature of 34°C (air fully saturated). These conditions are severe, but are not unrealistic, in terms of representing a mine emergency situation in a deep, laterally extended mine where ventilation has been disrupted. Further spot tests were then undertaken at temperatures ranging between 27°C and 34°C.

2. Evacuation Simulation, Work Rate and Treadmill Calibration

In devising the climatic chamber trials, an objective was to ensure, as far as practicable, that environmental conditions and work carried out by the test subjects were broadly representative of current underground conditions. Towards this, information was sought on the primary escape routes at deep, hot mines in the UK in order to establish typical gradients, and whether these could be simulated. This assessment included Harworth, Maltby, Stillingfleet, Thoresby and Welbeck. The method of assessment used was primarily inspection of mine plans and consideration of local knowledge by MRSL staff who visit these mines on training exercises.

It was not considered feasible to account fully for the physiological stresses involved in an evacuation, including possible disturbance to mine ventilation, low visibility effects, smoke irritation or variable floor conditions. It is fair to say, however, that these additional stressors would probably result in an increased effective work rate. Communication with Ms M. Hanson, Ergonomist and Heat Stress Specialist, suggested that certain standards be examined to estimate work rate/metabolic rate. UK standards include BS EN 28996:1994 (detailing methods of determining metabolic rate) and BS EN 27243:1994 (which provides 'typical' classifications of metabolic rate). A summary of metabolic rate categories from BS 7963:2000 was also considered relevant as follows:

Metabolic rate class (typical activity)	Metabolic rate per unit area of body surface (Wm^{-2})
0 Resting	65
1 Low (e.g. walking in easily accessed areas)	100
2 Moderate (e.g. walking in congested areas or with limited head room)	165
3 High (e.g. heavy manual handling)	230
4 Very High (e.g. rapidly climbing stairs)	290

The above compare reasonably well with figures drawn from individual studies (based on ISO 8996, Ergonomics - Determination of Metabolic Heat Production, 1990), which suggest walking type activities have a 'moderate' work rate, with indicative figures as follows:

Walking on the level, 2 kmh^{-1} *110* Wm^{-2}
Walking on the level, 5 kmh^{-1} *200* Wm^{-2}

The influence of load carried on metabolic rate is significant. The following provides an indication of typical metabolic rate at two speeds and for various loads [Sawka and Kent 2001], but is not adjusted per unit area of body surface, and includes basal metabolic rate:

Work Activity	Typical Metabolic Rate (W)
Walking on hard surface, 3.6 km/hr, no load	210
Walking on hard surface, 3.6 km/hr, 20-kg load	255
Walking on hard surface, 3.6 km/hr, 30-kg load	292
Walking on loose sand, 3.6 km/hr, no load	326
Walking on hard surface, 5.6 km/hr, no load	361
Walking on hard surface, 5.6 km/hr, 20-kg load	448

It is noted that rescue staff will each typically carry a load of 30 kg or more, comprising breathing equipment, lamps, tools, protective clothing, boots etc. This load leads to increased metabolic rate, oxygen demand and heat strain potential. Antekeuer and Lottner [1999], in an extensive series of tests, confirmed the imperative requirement to reduce breathing apparatus weight if strain on rescue staff is to be managed effectively. Of further note in their studies was that long-duration open circuit breathing apparatus produced heart rates up to 15-20 bpm higher than for closed circuit (mines rescue) breathing apparatus, primarily due to the additional cylinder weight of the former.

Bethea and Parsons [2002] provide a useful comparative review of standards and guidelines pertaining to ergonomics of the thermal environment. They also point out that whilst measurement or estimation of metabolic heat production is a fundamental requirement, there are significant practical difficulties in making accurate estimations of metabolic heat production from activity. Estimations of metabolic rate can be subject to errors as great as 60%. The use of ISO 28996 data, empirical equations designed specifically for an activity, and indirect calorimetric measurement methods are identified as possible methods. Interviews by Bethea and Parsons with UK industry safety professionals confirm there is little expertise in the measurement of metabolic rate - (most currently use wet bulb globe temperature (WBGT) tables or American Conference of Governmental Industrial Hygienists Threshold Limit Values (ACGIH TLVs) - and that measurements taken show large variation, both between measurements of different workers doing the same task, and between different measures taken on the same worker. Acknowledging the uncertainty when using published metabolic rate estimations, consideration was given to the possible need to separately simulate both level and grade walking.

Simulating Level Walking

It was proposed that two treadmills be assigned to each subject. The principal treadmill used to simulate level walking was set to have minimum resistance, with the test subjects free to regulate their pace to that which was individually comfortable. It was noted that the treadmills, even on minimum resistance, had a slight grade and required some effort to overcome the irreducible frictional and other mechanical losses of a self-powered treadmill. It is speculated that this work rate was probably of the same order as the work rate associated with variable under foot and roadway clearance conditions encountered underground and when walking on the level. One alternative option would have been for test subjects to walk around the periphery of the climate chamber. However, the work rate at any particular speed would have been lower than that experienced underground. Furthermore, since the physiological monitoring equipment was hard-wired, the test subjects could not have been monitored whilst walking around the chamber. It was therefore concluded that in order to simulate level walking underground, a mechanical treadmill set to minimum resistance and inclination would be used.

Simulating Grade Walking

It was proposed that a second treadmill would be used to simulate underground gradients, as required. The primary considerations here were:-

- the nature of the gradients to be simulated and
- the calibration of the treadmill

It was determined that the treadmills were mechanically simple affairs, subject to variance in braking force, both as a function of speed and elapsed use (and possibly environmental conditions). It was also recognised that headroom limitations within the chamber would prevent the treadmills from being too greatly inclined, noting that treadmill gradient is a standard means of modifying work rate. Given the variation in roadway gradients encountered underground, and the relative mechanical crudeness of the treadmill apparatus to model them, simplifications were considered necessary. It was proposed that the second treadmill be set up to simulate a single arbitrary underground gradient. It would then be possible by varying the parts of the cycle spent on the second treadmill to approximate the distance/time of travel involved underground. Various analyses of grade walking are given in Bobbert 1960, Margaria 1976, Minetti 1995, Pivarnik and Sherman 1990, Snellen 1960, Sun et al 1996.

Consideration was then given to the means of calibration of the treadmill and setting up a particular work rate. Calibration could, in principle, make use of direct or indirect calorimetry (for greatest precision and accuracy). Alternatively, an attempt could be made to replicate tests conducted by a group of subjects on a reference treadmill or gradient walk, possibly using heart rate (HR) as the physiological metric. This approach was considered somewhat less precise.

Calorimetric methods are usually employed in controlled laboratory environments. Measurement of heat produced by the body permits a direct estimate of metabolic rate. Such measurements are performed by direct calorimetry. Direct calorimetry is complex and is not routinely performed. Indirect calorimetry methods assume that steady state metabolism is aerobic and that at moderate work, anaerobic metabolism is a small part of credit oxidation [Wasserman et al 1967]. Measuring the rate of uptake of O_2 by the body provides an indirect estimate of the metabolic rate. Maximal oxygen uptake can be measured by open-circuit spirometry, or can be predicted from the peak exercise time or power output achieved during a standard maximal exercise test protocol, or can be predicted from sub-maximal exercise tests [Astrand 1960, Montoye et al 1986, Pollock et al 1980.]. The sub-maximal tests utilise heart rate responses to incremental workloads to predict VO_{2max} and are assessed as a safer method for the general population.

On balance, the precision of calorimetric methods was not considered justified against the approximations being made to simulate the underground environment, together with the simplicity of the test apparatus. There are simplified metabolic equations for estimating energy expenditure which are considered to be useful. The concept behind the development of metabolic equations is to estimate oxygen consumption when a subject is exercising in a given mode at a particular intensity. Data from numerous studies has been used to establish statistical prediction models and equations that can be used to estimate oxygen consumption. Clearly, this is less accurate than measuring oxygen consumption directly, but does avoid the cost and complexity of using metabolic analysis instrumentation. One such set of equations is the ACSM Metabolic Calculations.

There are three components in each equation; horizontal (H), vertical (V), and resting (R), where VO2 = H + V + R.

This can be simplified to the following [ACSM 2000, Swain and Leutholtz 1997]:

Walking: $VO_2 = 3.5 + 1.7(\text{speed}) + 0.3(\text{speed})(\%\text{gradient})$
Bench stepping: $VO_2 = 0.35(\text{rate}) + 0.025(\text{rate})(\text{height})$

VO_2 in $ml.kg^{-1}.min^{-1}$
Speed in $km.h^{-1}$
Rate in steps per minute
Height in cm

An alternative method, proposed in discussions with Mr Forster, HMIM RATO, Project Officer was to select a group of test subjects and have them use a calibrated laboratory treadmill, or have them walk a defined gradient or route, with measurements taken of heart rate. These measurements, possibly in conjunction with a repeat of the tests using the same subjects on the treadmill simulator, could be used to set up an equivalent work rate. Whilst there are several potential sources of error in this method, it was considered to be practicable.

Cycle ergometry was discounted due to difficulties in relating energy expenditure to that involved in level or grade walking.

3. Ensuring Safety of the Subject

All trial phases of the study were submitted to HSE's Research Ethics Committee for peer review and approval. The study adhered strictly to the process of informed consent, and largely followed guidelines and procedures developed for an earlier comparable trial by the study physician, Dr Andrew Booth [Hanson and Booth, 2000]. A qualitative risk assessment was undertaken. The key findings in terms of the significant risks identified and proposed monitoring and control measures were as follows:

TRIAL RISK ASSESSMENT

Potential Hazards	Potential Severity	Likelihood	Control Measures	Risk Factor
Cardiovascular hazards (excessive heart rate, stroke risk)	High	Low	Continuous heart-rate monitoring. Supervision by occupational physician. Conservative withdrawal criteria.	Low
Thermoregulatory hazards (heat stress, dehydration and significant discomfort)	High	Low	Continuous core temperature monitoring (climate chamber trials). Supervision by occupational physician. Conservative withdrawal criteria.	Low
Thoracic and naso-pharyngeal hazards (inhalation of hot air)	Medium-High	Low	Hot inspired air devices tested to ensure peak temperatures <50°C, or devices meet appropriate EN test standards.	Low
Psychological stress	Medium-High	Low	Subject screening. Instruction and information prior to tests. Post-test debriefing and reassurance.	Low
Ergonomic hazards (musculo-skeletal injury including strain injuries)	Medium	Low	Subject selection. Trial practice, instruction and monitoring.	Low
Slipping, falling and trips	Medium	Low	Adequate illumination, familiarity with route, clearance of obstructions.	Low
Dental hazards (damaged teeth and dentures)	Low	Low	Briefing on dental precautions and failure response.	Low

Physiological monitoring of all test subjects was used throughout the trials. Heart rate and body core temperature were monitored continuously. Withdrawal criteria were specified which took into account appropriate margins of protection and any temperature offset associated with the method of measurement (e.g. ear cavity versus rectal measurements).

The following physiological withdrawal criteria was utilised. Bethea and Parsons [2002] proposed comparable criteria.

- 38.5°C core (aural) temperature reached, or
- heart rate of 180 beats per min. /80% of age-related max. heart rate reached, or
- Physician decision (inc. other factors e.g. SCSR breathing difficulty), or
- Subject request for termination, or
- 1.5 hours elapsed travel time reached.

The key physiological withdrawal criterion was considered to be the individual's core body temperature. The study medical staff were able to supervise this parameter continuously during the trials.

4. Physiological Monitoring of Core Temperature and Heart Rate

Prior to selecting instrumentation, a review of core body temperature measurement and heart rate monitoring was conducted. This included a site and measurement accuracy comparison with 'gold standard' clinical methods.

Core Body Temperature Measurement

The preferred sites for measuring core body temperature are considered to be those closest to the hypothalamus, the temperature-regulating centre. The temperature in the pulmonary artery, esophagus and bladder can be monitored to measure core values, but these sites involve invasive thermometry. Traditionally, the oral, rectal, and axillary sites have been utilised. Some clinicians consider the rectal site to be the most accurate. However, rectal measurements do not respond quickly to induced heat changes in the body. Reference is made to reviews of clinical thermometry [Holtzclaw 1998, Klein et al 1993, Milewski et al 1991, Cattaneo et al 2000].

A preferred temperature site of more recent adoption is the aural canal. True tympanic membrane temperature measurement is taken deep inside the skull, and is not subject to the errors that can affect oral, rectal, axillary and ear temperatures. There are two types of instruments available to make the measurement.

- A long thin thermocouple probe that must come in contact the tympanic membrane. There is much historical data on the efficacy of tympanic thermometry. Ferra-Love [1991] and Klein et al [1993] found pulmonary artery and tympanic measurements to be highly correlated. However, invasive tympanic methods never gained wide acceptance due to the risk of injury to the membrane.
- Infrared measurement of tympanic membrane temperature by non-contact means. This eliminates risk of injury to the tympanic membrane.

There are three types of infrared thermometers:

- tympanic
- ear
- arterial heat balance

Results of studies using (infrared) aural measurements are however conflicting, with some claiming there is a strong correlation with pulmonary artery temperature, whilst others indicate the method has high variability. Problems with technique and probe placement are areas of concern. A number of studies have been undertaken [Childs et al 1999, Erickson and Meyer 1994, Fremstad et al 1993, Imamura et al 1998, Matsukawa et al 1996, Modell et al 1998, Rohrberg et al 1997, Shibasaki et al 1998, Smith and Fehling 1996]. Tests on specific infrared instruments claim they are unreliable in clinical practice (e.g. Modell et al 1998), whilst a statistical approach to method comparison was highlighted as important by Bland and Altman 1986.

Within the trials, an objective was to eliminate the variability arising from otoscopic application technique and to get as close as possible to true tympanic thermometry. Aural canal thermistor sensors are the preferred instrument under extreme environmental condition, and are used by the military for monitoring individuals suffering from heat or cold stress. The thermistor types selected for this application were supplied within a moulded plug which fits, without discomfort, into the mid-outer part of the aural canal. In order to minimise external environmental influences on measurement accuracy, the thermistor and ear were covered in thermal insulation and then enclosed by an insulated earmuff. This arrangement was considered to be an optimal compromise between invasiveness, wearer comfort, thermal stabilisation time and core body temperature measurement precision.

The manufacturer individually calibrated the data logger channels and aural thermistors. The two point calibration results were as follows:

Calibration Data for Aural Thermistors

Converted Thermistor Temp. Reading, °C (res. meas. error +/-0.01°C) Calibration Bath Temperature: 35.70°C (max. error +/- 0.03°C)	**Converted Thermistor Temp. Reading, °C (res. meas. error +/-0.01°C)** Calibration Bath Temperature: 38.02°C (max. error +/- 0.03°C)
Probe No. 1 35.75	Probe No. 1 38.07
Probe No. 2 35.74	Probe No. 2 38.06
Probe No. 3 35.78	Probe No. 3 38.11
Probe No. 4 35.69	Probe No. 4 38.02
Probe No. 5 35.62	Probe No. 5 37.94
Probe No. 6 35.73	Probe No. 6 38.06
Probe No. 7 35.78	Probe No. 7 38.10
Probe No. 8 35.78	Probe No. 8 38.09
Probe No. 9 35.72	Probe No. 9 38.04
Probe No. 10 35.66	Probe No. 10 37.98

A number of open air thermistors were employed around the environmental chamber in order to monitor dry bulb temperature and measure temperature stratification within the chamber.

During the trial phase, a swallowable sensor pill technology ("CorTemp" measuring system supplied by HQI Technology Inc.) was identified. This technology is being used by the US National Institute for Occupational Safety and Health (NIOSH) to investigate core body temperature behaviour in underground work settings. The approach is representative of 'intestinal' temperature measurement, which is somewhere between esophageal and rectal measurement methods in terms of response time. **Figure 3.1** shows typical response time characteristics. NASA has evaluated the sensor pill technology [Lee et al 2000], and has partially confirmed these assumptions. In **Figure 3.2**, taken from the NASA evaluation report, the 'intestinal' data trends correspond with the swallowable sensor pill. The NASA test data confirmed variability in sensor response time, dependent on the subject. This possibly reflects the sensor clearance time from the body of 7 -45 hours within a range of subjects, and uncertainty with regard to positioning within the intestinal tract. The use of intestinal core temperature measurement is affected by the location of the sensor pill in the intestinal tract. Location is variable and uncertain and results are greatly affected by drinking while the sensor is in the stomach. It is likely that drinking cool fluids will result in recorded core body temperature measurements being lower than those measured at more conventional clinical sites.

Using Heart Rate to Measure Exercise Intensity

The basic physiological principle of using heart rate (HR) to measure exercise intensity is that as work rate increases, oxygen consumption (VO_2) and HR increase in a linear relationship until near maximal intensities. The relationship between HR and VO_2 is given overleaf. A key aspect is knowledge of the subject's HR_{max}.

In a physiological laboratory setting, it would be appropriate to undertake a maximal aerobic power test during which VO_2, HR and blood lactate concentration would be tracked as work intensity increased. From this laboratory test, maximal HR (HR_{max}), maximal power (Watts), VO_{2max} and lactate threshold (LT)/ heart rate (HR) can be determined (HRLT). The subject's HR at different power outputs and percentage VO_2 can be determined.

Studies of a variety of heart rate monitors (HRMs) confirm they correlate at a level of 0.99 when compared to electrocardiography (ECG) over a range of 55-177 beats/minute and that 90% of the time measured errors are within 8 beats/minute [Laukkanen and Virtanen 1998].

Relationship of percent of HR_{max} and VO_{2max}

% Max VO_2	% Max HR
50	66
55	70
60	74
65	77
70	81
75	85
80	88
85	92
90	96

Factors affecting Heart Rate

There is a potentially large inter-individual and intra-individual variation in heart rate, HR. Influencing factors include stress, illness, and recovery from previous work, medications and food. One phenomenon to note is 'cardiac drift', the increase in HR seen over time while exercising at a constant workload. Some studies suggest HR can increase by 20 beats/min during constant work rate exercise lasting 20 to 60 minutes. Ambient environmental conditions and hydration status can significantly affect cardiac drift. The presence of high heat and humidity cause cardiac drift to be more pronounced. HR, therefore, tends to be higher for a given work load in hot conditions than in cooler, dryer conditions.

Physiological Instrumentation

The physiological monitoring equipment used in these trials comprised a purpose-designed data logger (one per subject), which had a dedicated three lead ECG heart rate monitoring channel and capacity for a number of thermistors. The instrumentation for the trial was sourced from Grant Instruments/Eltek Limited.

In the pilot phase of the study, a problem was identified with the cardiac monitoring instrumentation. The study physician observed the instrument was not providing readings, which correlated adequately to real-time cardiac response. Arrangements were made to check the instrumentation against the ECG and sub-maximal cardio-vascular fitness assessment clinic instruments used by Business Healthcare Limited. These tests confirmed the initial observations. Discussions with the physiological monitor/data logger manufacturer led to changes to the statistical settings used within the instrument. These changes resolved the problem, with confirmatory checks made against ECG readings of heart rate, within the range 60 - 130 bpm. Various additional tests were also carried out to determine the sensitivity of the instrument to electrode placement and to finalise the routing and management of instrument leads on the subject.

Whilst, the instrumentation performed to specification in the trials, significant problems were experienced in maintaining proper ECG electrode contact. This was attributed to the difficulties in preventing electrode lift and gel depletion when subjects sweat profusely. The entire commercial electrode set which was evaluated showed gel leaching and detachment problems. The study medical staff made manual interpretations of pulse rate, which confirmed that all subjects were maintained within their age-adjusted heart rate limits.

The physiological data for the trials, whilst primarily intended to ensure the health and safety of subjects, was recorded against elapsed time and elapsed distance travelled on the treadmill. This permitted individual thermal stress to work rate data, distance travelled and walking speed/behaviour to be analysed. The data was recorded as primary data within the logger, with a back-up within the data trending software. In order to accomplish the elapsed distance measurement, a modified treadmill flywheel sensor had to be devised. Tests were conducted to compare the effort required to move the mechanical treadmills compared with level walking. A range of treadmill gradients was examined towards ensuring maximum representativeness.

5. Experimental Protocol Refinement

The initial phase of the experimental test programme was used for pilot testing and refinement of the trial protocol. This considered the following:

- Ensuring the programme was of manageable size and could be delivered in sensible time.
- Examining the scope of tests to offer reasonable statistical significance and scope in order to extrapolate the findings to the general workforce population.
- Examining the test variables/variations to ensure key issues were addressed first.
- Defining baseline testing and referencing requirements.
- Accounting for shift pre-warming as necessary.

The available volunteer pool population, entirely comprising MRSL staff, determined the characteristic of the cohort group. There was a requirement to represent, as far as practicable, the range of ages, body mass index, cardio-vascular fitness and acclimatisation capability. An examination was made of the respective benefits of:

- random selection of subjects
- selection of a set of individuals which broadly span the population, and
- biasing the selection to give greater weighting to sensitive sub-groupings.

The latter approach would better account for mine staff management, contractors and visitors etc.

Even with a relatively modest number of subjects, it was recognised that the total number of tests required could become significant (to include baseline tests, different temperatures and humidity, effects of respirator type, effects of pre-warming, effects of clothing). Accordingly, the trials were structured so as to concentrate first on resolving central issues, with a 'second tier' of tests examining other factors such as, for example, the impact of clothing. Wearing of the industry standard W95 FSR was not carried out, since without the presence of CO, the additional physiological burden would be small, essentially a small increase in breathing resistance. Hence the emphasis was on testing with a hot air model.

The original submission to HSE's Research Ethics Committee incorporated initial views on a test protocol, including options for accounting for shift work pre-warming. These options included simulation of walking inbye, together with a period of work involving either:

- Undertaking cycles of work and rest involving block wall building and dismantling, or
- Simulation of coal face working, involving crouching, lifting and movement over irregular surfaces.

These exercises were proposed on the basis that they were reasonably representative of the underground workforce travelling to workings and mine work activities there. After discussion with the Study Physician, it was considered reasonable to introduce certain simplifications. One criterion was to ensure that the musculo-skeletal set and work rate was broadly equivalent to the intended underground work pattern. A further simplification involved assigning part of the treadmill activity as pre-heating activities, and assigning subsequent exercise to the evacuation phase following an emergency occurring. It was judged impractical to account for sweat depletion mechanisms, such as might occur towards the end of a shift in hot and humid conditions.

Initial chamber treadmill tests were conducted at 23°C (normal humidity) and then at 36°C (100% humidity) to ascertain what constituted reasonable pre-warming exercise activities, and how long subjects could be exposed to extreme temperatures before core body temperature exceeded the withdrawal criterion of 38.5-38.6°C. Even with relatively moderate work rates, it was observed that at high temperatures with the air fully saturated, the safe period in the chamber could be as little as 30 to 40 minutes. On this basis, it was not judged feasible to incorporate a high work rate component within the treadmill test procedure (designed to simulate walking up significant gradients). It was considered likely that subjects would be prematurely withdrawn from the tests due to their core body temperature exceeding safe limits.

It was agreed to restrict exercise within the trials to use of the treadmills at minimum resistance and inclination setting, broadly equivalent to moderately strenuous walking. The subjects were encouraged to pace themselves and to rest when they felt it necessary. Walking rates varied between 2 – 4 km/h.

Trials on the chamber temperature regulation system indicated that a mean maximum chamber temperature of 38°C fully saturated could be maintained. However at this temperature, the chamber was subject to a significant heat loss when doors were opened, in spite of the negligible air velocity in the chamber (<0.5 m/s). Subsequent tests showed that the target mean chamber temperature of <34°C fully saturated could be maintained with better stability. Generally, it was necessary to monitor the chamber temperature and regulate manually the chamber temperature and humidity controller.

Significant vertical stratification in temperature was noted within the chamber. Chamber temperature probe measurements were made during the tests at ceiling height (5 cm from lining), mid-torso height (left and right hand sides of treadmill row), and, close to the chamber floor (20 cm above tiled surface). Temperature and humidity measurements were confirmed by periodic Casella whirling hygrometer measurements.

The chamber temperature stratification resulted in highest local thermal stress to the head and neck. This was observed, in practical terms, by the efforts of some test subjects to lower their heads during the test runs, specifically to reduce the sensation of heat about the head. Whilst the whole peripheral cardio-vascular system and associated environmental conditions must be considered in terms of the body's overall ability to maintain thermoregulation, there is undoubtedly a complex relationship between head temperature, perception of heat and tolerability of conditions. A number of procedural modifications were evaluated in an attempt to reduce chamber temperature over-shoot and stratification. This included judiciously turning off the ceiling heat injection system and introducing modest air movement within the chamber. These measures reduced overall chamber temperature, but largely at the expense of loss of temperature control accuracy. There is an identified requirement for further investigation as to whether there is an enhanced physiological response, greater distress and possibly earlier withdrawal due to ambient temperature stratification.

The experimental arrangement used within the climate chamber trials can be readily appreciated from **Figures 3.3** through **Figure 3.8**. A summary of the trial protocol procedures is given in **Annex 1**.

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Section 3: ANNEX 1

Trial Protocol Procedures

The Trial Protocol essentially involves three phases:

A. Establishing the baseline, reference response for each individual.
B. Establish response under identical circumstances, but whilst wearing a hot-air model filter self-rescuer.
C. Establish response under identical circumstances, but whilst wearing a chemical oxygen SCSR.

The trial involves establishing a baseline response, where individuals provide their own reference data set. This effectively replicates the conditions in B and C above, but without a respiratory protective device being worn. In order to reduce any systematic effects, for example initial anxiety at the first test, the three test phases A, B and C should be randomly mixed.

The trial procedure is essentially as follows:

- Ensure treadmill belt friction surface has been lubricated with silicone oil and adjusted if necessary for tracking.
- Ensure external recovery area is prepared as necessary with fans, drinks, seating etc.
- Ensure insulating cotton wool, ear protectors and relevant tapes are inside chamber (to pre-heat them).
- Sterilise aural thermistors and modified ear defender housings.
- Check portable computer and instrumentation status. Check there is sufficient residual battery life in the data loggers.
- Check aural thermistors, heart rate and odometer instrument leads and connectors.
- Bring climate chamber up to nominal temperature and humidity (34°C fully saturated).
- Wipe chamber observation windows with surfactant.
- Start Eltek 'Darca' logger software. Check data communications can be established between the loggers and portable computers.
- Check channels can be metered. Adjust graph scales and alarm points as necessary.
- Clear the previous logger data.
- Have test subjects made ready, two subjects maximum per run.
- Study physician briefs subjects on the nature of the trial, procedures, possible discomfort and confirms they may stop at any time, or, may be withdrawn by the nurse or physician.
- Confirm written consent has been obtained and records maintain subject anonymity.

- Check subjects are appropriately dressed and equipped; vest with Velcro fastenings, shorts, boots etc.
- Denature relevant chest and rib areas and fit ECG electrodes.
- Subjects enter chamber, aural canal thermistors are fitted together with insulation and earmuff.
- Subjects relax for 10 minutes to allow core-body temperature measurements to stabilise and instrumentation checks to be made. Adjust instrumentation wires as necessary.
- Subjects warm-up by walking at a steady pace for 10 minutes on treadmills (subsequently reduced to 6 minutes warm-up period). Monitor core body temperature, heart rate and odometer outputs.
- Stop subjects at appropriate mid-point. Instruct them as follows:
- Either
  - Continue walking at a steady evacuation pace (baseline test), or
  - Don the SSR 30 chemical oxygen SCSR, or
  - Don the hot air FSR model.
- Subjects continue until they wish to withdraw, or, are instructed by study physician to stop.
- Rapidly withdraw subject(s) to designated recovery area and monitor recovery.
- Stop data logging. Download and process data files.
- Make back-up copy of data.
- Study physician issues confidential identity code for all data files and written notes. Identity of trial subjects maintained anonymous thereafter.
- Stand down test subjects. Conduct post-test medical checks and debriefing.
- Prepare chamber for second run, if required.

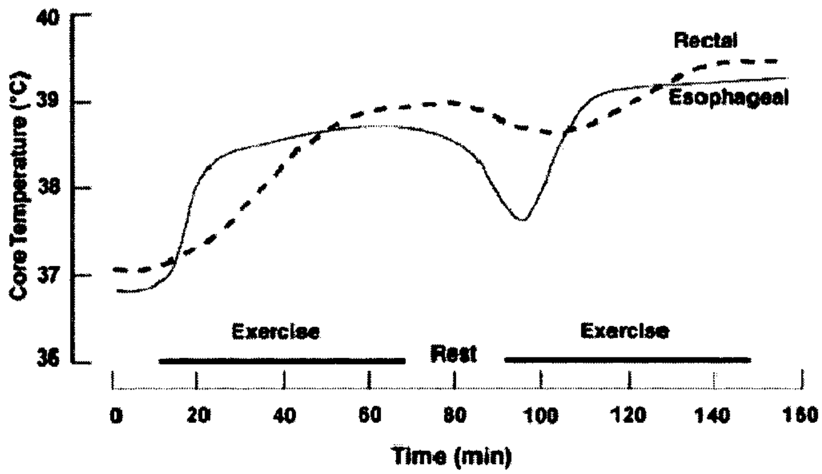

Figure 3.1: Response Time Characteristic at Rectal and Esophageal Locations

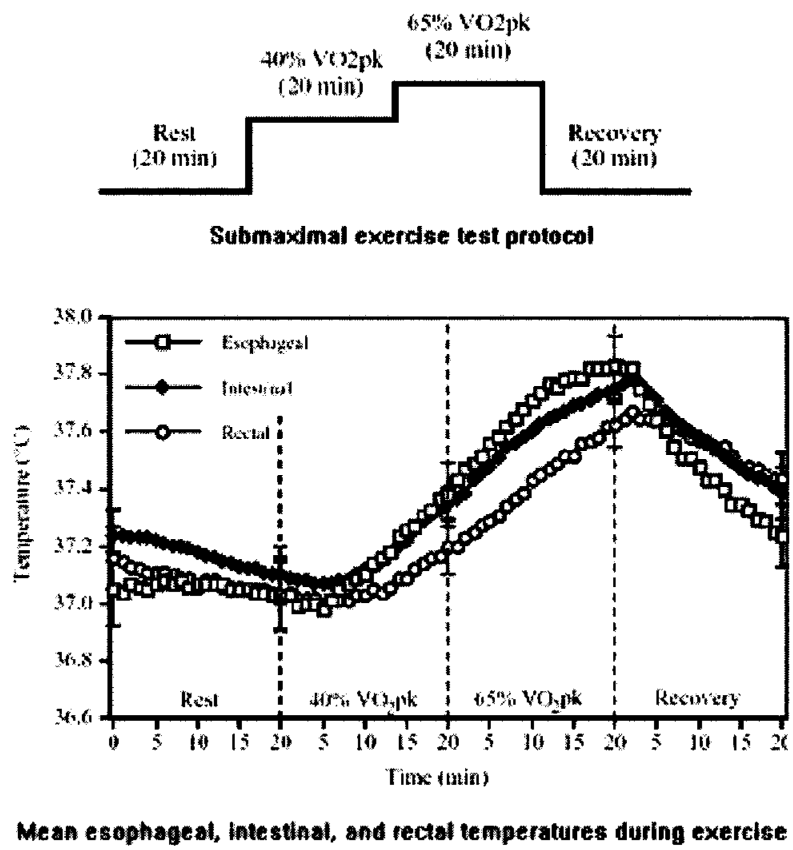

Figure 3.2: Temperature Response Time Characteristic for Submaximal Exercise

Figure 3.3: Climate Chamber, Treadmills and Monitoring Instrumentation

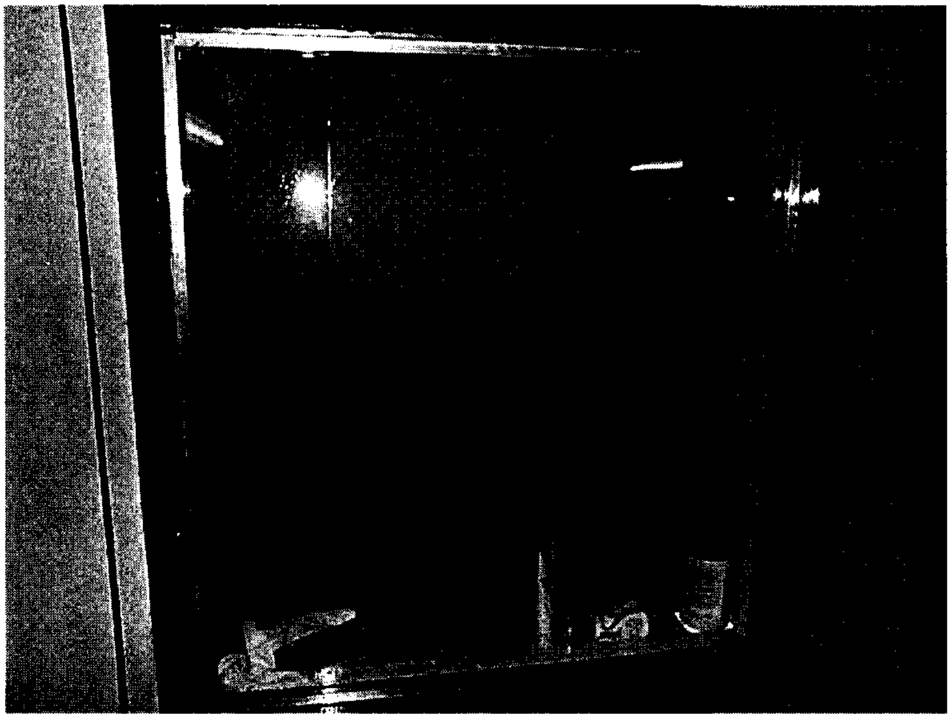

Figure 3.4: Observation Window and Adjacent Data Acquisition Room

Figure 3.5: Portable Computers for Real-Time Data Recording and Display

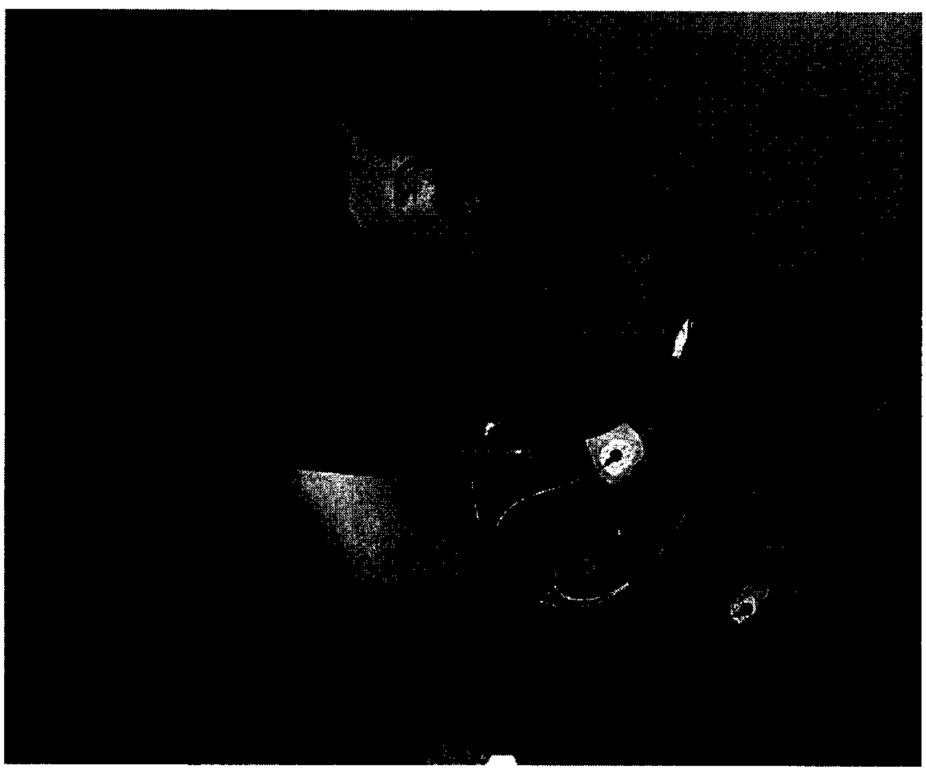

Figure 3.6: Study Physician Fitting Heart Rate Monitor Electrodes

Figure 3.7: Subject Exercising with SSR30 SCSR

Figure 3.8: Subjects Exercising in High Heat and Humidity