



MSHA Request for Information – Section D. Rescue Chambers

1) Should rescue chambers be required for coal mines?

Rescue chambers have been used in metalliferous mines in Australia since the 90's. These units were initially very basic and consisted of a converted C Container with face masks fed from a compressed air source. Although these units provided some limited defense in the event of an irrespirable atmosphere they have numerous hazards including:

- Masks requiring continual servicing to ensure operation of demand valves (due to lack of use),
- Sealing of masks for persons with beards (up to 25% leakage),
- Lack of duration (generally 6-8 hours),
- Reduced ability to communicate,
- Reduced ability to administer first aid,
- No means of removing metabolic heat (approximately 1 degree Celsius increase per 60 minutes entrapped),
- No battery power once mine power fails,
- Impossible to drink water with masks and a contaminated atmosphere.

Consider as an example, a chamber to contain 12 persons with air fed masks. In 3.7 hours the Carbon Dioxide (CO₂) will have reached 10% (100,000 ppm) which could result in unconsciousness and death. In 9.5 hours the CO₂ will have reached 25% (250,000 ppm) which will kill immediately. This basically means in these instances, anyone who elects to take off their mask due to thirst or injuries would be killed with prolonged exposure or at worst immediately.

The current proposed legislative changes (Senator Specter) which propose surplus oxygen supplies for up to 96 hours would be rendered useless as persons would perish from either thirst or removing their mask due to thirst before running out of oxygen.

These extreme hazards have been overcome by the introduction of scrubbing systems. Scrubbing units are self-contained units that are designed to clean air in a confined space where human life needs to be supported over a period of time. The purpose is to remove the CO₂ and Carbon Monoxide (CO) from the air, reducing the risk of CO₂ and CO poisoning.

Since 2000 the metalliferous industries in Australia have been using portable refuge chambers and they are now generally accepted as standard requirements under the Western Australian Refuge Chamber Guideline 2005 and the Queensland Mining & Quarrying Safety & Health Regulations 2001.

The Australian Metalliferous industry has benefited drastically by the introduction of refuge chambers with refuge chambers being employed in several mine fires with positive results. The latest of these incidents was on the 9th of March 2006 at a Nickel Mine in Kambalda Western Australia. This incident involved an underground loader fire and nine (9) persons taking shelter in a portable MineArc refuge chamber for 4 hours before rescue teams arrived at the chamber. Although, there are succinct differences between coal and metalliferous mining the technology can be applied across almost completely.

Currently most underground coal mines have not had refuge chamber technology applied to them due to two prevailing factors:

- 1) Refuge chamber technology is relatively new and companies involved in manufacturing chambers have been working predominately with the metalliferous industry at their request.
- 2) Most coal mines maintain a walk out procedure in an emergency and thus opted to use change over stations with long duration breathing apparatus (this is currently changing with some mines in Australia and New Zealand now opting for refuge chambers).

It is prudent to remember that Australia's last mine disaster was the Moura No 2 mine in 1994. In this incident a coal heating was not recognized and a subsequent explosion occurred. There were twenty-one persons working underground at the time. Ten men from the Northern area of the mine escaped within thirty minutes of the explosion but eleven from the Southern area died in the mine as a direct or indirect result of the first explosion. Twelve years ago there was not the technology available to even consider refuge chambers. Unfortunately for our industry the driving factor for improvements in safety, is a significant loss of life.

It is evident from all discussions, that coal mines will maintain an 'evacuate if possible' standard. This is ultimately the correct approach to take due to the fact that coal itself is a fuel source and can burn for extended periods. However, in reading the recently issued MSHA 'Emergency Mine Evacuation Temporary Standard' it is obvious that Refuge Chambers should be incorporated in mine emergencies. The standard outlines on Page 36, *'An explosion or mine fire creates a thick, smoke-filled atmosphere in the mine which hampers a miner's ability to quickly evacuate because miners may panic or become disoriented.'* When examining mine disasters such as Moura or Sago, it is often only persons in sections of the mine remote to the fire or explosion that escapes. For persons working within the vicinity of the fire or explosion the smoke may reduce visibility to a few feet necessitating a barricade option (due to disorientation, injury or other). It is for these people that refuge chambers could provide a life saving option when compared to current standards and procedures.

2) *What characteristics should the refuge chambers take?*

MineARC systems are currently manufacturing an intrinsically safe portable underground coal Refuge chamber. The characteristics for the refuge chamber are similar to that which is currently used in the metalliferous industry with some adjustments for the specific requirements of underground coal. The chamber includes the following:

1. CHAMBER	
Capacity	12 persons up to 30 persons
Entrapment Time	36 hours Minimum
Construction	<ul style="list-style-type: none"> ▪ Walls and Roof - 5mm Steel plate Pressed Sections. ▪ Collapsible for low seam entry with hydraulic cylinders for lifting the unit into position. ▪ Base - 100mm RSJ Section. ▪ Base fitted with steel wheels for easy maneuverability. ▪ Lifting Eyes located on all four external corners. ▪ Fully integrated Air locks for intrinsically safe area requirements.
Positive Pressure	Air receiver storage for pressurization of unit and air lock flushing and re-pressurization of refuge with interlocking controls.
Floor	Non Slip Floor Covering
Sealing Door External (ZONE 1)	Outward opening external door due to internal pressurisation and flushing within Zone 1 with a Single locking handle internally and externally linked with door locking systems for zone 2 and safety override for complete system shut down if require.
Seal	Rubber Compression extruded seal externally fitted
Sealing Door Internal (ZONE 2)	Outward opening door due to internal pressurisation of zone 2 and safety override to ensure Zone 1 door is sealed before the door releases and flushing of Zone 1 has occurred also having a Single locking Handle internally and externally linked with a safety override for complete system shut down if require.
Seal	Rubber Compression extruded seal externally fitted.

1. CHAMBER	
Painting	<ul style="list-style-type: none"> ▪ Unit blasted to 2.5 grit internally and externally. ▪ Primer - Two pack internally and externally – Colour white. ▪ Internally - Painted in white two pack water based epoxy (food grade). ▪ Externally - Painted in white two pack enamel. <p><i>Please Note: Refuge Chambers must be painted internally in inorganic water based epoxy suitable for human occupancy.</i></p>
Signage	<ul style="list-style-type: none"> ▪ External – Reflective 100mm green striping horizontally around complete unit. ▪ External - Pressure sensitive adhesive safety and operational signage. <p>Internally – Pressure sensitive adhesive safety and operational signage.</p>
Viewing Windows	<ul style="list-style-type: none"> ▪ 8 Bolt flange reinforced backing plate ▪ Secured Poly-carbon viewing window 12mm thick

2. ROOM EQUIPMENT	
Seating	<ul style="list-style-type: none"> ▪ Bench seats with canvas cushions along side walls of chamber.
Storage	<ul style="list-style-type: none"> ▪ Under seat storage for water, first aid supplies and additional equipment.
Alarm Plan	<p>Operation Manuals and Procedures provided in English and language of choice.</p> <p>Internal Safety and Operational Signage in English and language of choice.</p>
Toilet	<ul style="list-style-type: none"> ▪ Self Contained Toilet with capacity for 20.5 litres ▪ Supplied complete with 1 sachet of "Secure" Holding tank deodorant and cleaner.
Fire Extinguishers	<ul style="list-style-type: none"> ▪ Internal – ABE Dry Powder 500gms. ▪ External – ABE Dry Powder 9kg. <p>NB – Fire Extinguishers are for external use only.</p>

3. ELECTRICAL EQUIPMENT	
Emergency Lighting	24 volt system fully operational on mains power and battery back up.
Electrical Connection	Zone 1 rated Terminal Box (to external supply).

3. ELECTRICAL EQUIPMENT	
Back Up Supply	<p>Emergency Battery to power the Scrubbing System, Lighting and Air Conditioning in case of failure of the normal electricity supply.</p> <p>36 hours UPS Battery Back up system dry gel maintenance free.</p> <p>Charged from external power and will stand alone for 36 hours once all external power sources fail.</p>
Energy Requirements	<p>220-240 Volts AC. 50-60 Hz Free Load Amps – 10</p> <p>110 volt systems available upon request.</p>
Lighting	<ul style="list-style-type: none"> ▪ External Lighting - Red and Green warning lamps located next to the Chamber Door ▪ Internal lighting – Fluorescents
4. BREATHING AIR SUPPLY	
<p>External Compressed Air</p> <p><i>Primary source of breathable air</i></p> <p>If available from Mine source</p>	<p>Low pressure air supply (2 bars) for normal use. Compressed Air sourced externally.</p> <ul style="list-style-type: none"> ▪ Externally - connection via a 1" BSP Port to a non-return valve, prefilter and coalescing filter to 0.01 micron with indicator and carbon odour removal filter. ▪ Internally - passes through chamber bulkhead to 1" isolating ball valve and ¾" pressure reducing flow regulator and auto muffler for silencing <p><i>Australian Standards 1716-15</i></p>
<p>Medical Oxygen</p> <p><i>Secondary source of breathable air</i></p>	<ul style="list-style-type: none"> ▪ Oxygen Cylinders Medical - 3 x 7,600 litre cylinders (to be supplied by client) ▪ Sabre SF-Bull-11F2 Medical Regulator with flow selection from 1-50 persons, calibration every 5 years.
<p>Oxygen Candle</p> <p><i>Final source of breathable air</i></p>	<ul style="list-style-type: none"> ▪ 2,600 litres of oxygen produced within 60-70 minutes of ignition. ▪ Can only be ignited within the refuge chamber safe zone ▪ Military approved – see Material Safety Data Sheet for more information ▪ Striker, ignition Cap and pliers included.
5. REGENERATION SYSTEM (SCRUBBING SYSTEM)	
Carbon Dioxide (CO ₂)	<p>Regeneration system for long-term duration if normal air supply fails. Stored inside the chamber with one switch operation and sized for occupants in a sealed system.</p>

5. REGENERATION SYSTEM (SCRUBBING SYSTEM)

Carbon Monoxide (CO)	CO Scrubbing for endogenously produced CO from occupants within the chamber @ 15,000 litres per hour.
Chemicals	See safety data sheets attached
Air Monitoring	Gastec GV100 Gas Sampling Unit with test tubes for Carbon Dioxide- CO ₂ , Carbon Monoxide-CO and Oxygen- O ₂ .

6. AIR CONDITIONING SYSTEM

<p>Air Conditioning</p> <p>Refrigerant is R22</p> <p>Zone 1 rated unit for explosive atmosphere with an operating temperature of 125 Fahrenheit.</p>	<p>Air conditioning of the chamber is supplied by a split system air conditioning unit operated by external power under normal conditions, but switching over automatically to the battery backup system when external power fails.</p> <p>Condenser situated externally with undercover protection.</p> <p>Separate battery backup system incorporating UPS (Uninterruptible Power Supply)</p> <p><u>Please Note:</u> <i>Without Air Conditioning occupants will develop heat stress in a very short period of time and the refuge chamber will not be able to support life. Therefore it is a necessity that Air Conditioning is available for full entrapment time. (Each occupant will produce 200 watts of heat and this must be removed otherwise significant heat build up will occur).</i></p>
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3) *How long should they support a breathable environment?*

This is probably the most debatable of the questions posed. To attain a realistic time duration research needs to be completed into previous mine explosions and fires. To date, suggestions have been made anywhere from 16 to 96 hours of oxygen supply. The real number needs to be determined using empirical data from previous underground coal mine emergencies within the United States: This must consider the following points:

- Types of emergencies generally encountered (explosions, coal fires, vehicle fires etc).
- Time for fires to extinguish and contaminant levels abate.
- Time taken to mobilize Mine Rescue personnel.
- Time taken to re-enter working area where emergency has occurred.
- Mine Ventilation systems.

Within the metalliferous industry the adopted standard was a minimum stand-alone duration of 36 hours. This figure has been derived on the basis that 90% of incidents involving an irrespirable atmosphere are as a result of a diesel powered vehicle fire. These fires generally extinguish themselves within 6 hours and due to the possibility of a tire explosion can be approached within 24 hours. This gives the refuge chamber a six hour buffer.

As outlined in Question 1, suggested time durations of over 48 hours are rendered useless with a face mask system and a contaminated atmosphere. Persons will suffer severe dehydration within 24 hours and perish within 48 hours.

MineARC intend to introduce a 36 hour duration chamber, however additional duration can be achieved by simply adding more chemical, batteries and oxygen cylinders. These chambers are routinely used as storage locations for additional SCSR further extending duration times. The 36 hour duration is practical based on the legislative changes to emergency response and mine rescue training being implemented by MSHA.

4) *How many people should they support?*

Currently MineARC manufactures units for the metalliferous industry in 30, 20, 15, 12 and 8 persons. MineARC's two coal chambers to be introduced to the US market, a standard 64" height chamber and a telescopic roof (29"-77") chamber will support 12 persons. This size has been considered optimal due to the height restrictions encountered in coal mines and the absence of Integrated Tool Carriers or Load Haul Dumps for moving the chambers around the mine.

The chamber size should recognize that other personnel such as supervisors, surveyors, geologists and service technicians may also need to use the facility. The number of such people in the workings from time to time can require provision for a refuge capacity more than double that determined from the size of the locally operating crew alone.

The advantage of a scrubbing style refuge chamber as opposed to a mask system is that additional persons can enter into the chamber once it has reached its nominal person capacity. The only affect of additional persons within the refuge chamber is a reduction in the duration of the chamber. In contrast a mask style system or storage point with additional SCSR can not accommodate additional persons if there aren't sufficient masks or SCSR.

5) *How many are required, how far apart should they be located?*

Studies already completed in the metalliferous industry (Brake) can be heavily relied upon for determining distance and location of refuge chambers. For persons who cannot escape the coal mine the initial problem confronting an underground worker in the event of a fire is securing an immediate supply of breathable air. In this instance the SCSR is used to immediately locate a refuge chamber.

It is recommended that the maximum distance separating a worker from a refuge chamber be based on how far a person, in a reasonable state of physical fitness, can travel at a moderate walking pace, using 50% of the nominal duration of the SCSR. If it is assumed that workers are equipped with SCSRs of nominal 30-minute (minimum) duration, at a rate of 30 l/min, then no-one should be expected to travel further than 2460ft to reach safety. This distance should be regarded as an absolute maximum because:

- The duration of the SCSR can be adversely affected by the wearer's physical fitness and state of agitation.
- Physical difficulties may be encountered while traveling.

As there is a tendency for explosions and fires to occur at the coal face or in the goaf, workers should have access to a chamber within the surrounding area. The chamber would be located on all active panels on the intake side. This is as there are often more workers around the coal shearer and the likelihood of entrapment is high in this area. As the chamber would be in close proximity to the fire the chamber must be located in an area which is unlikely to come in contact with the flames. Alternatively, the chamber can be fire proofed for up to two hours.

MineArc Systems are the largest supplier of underground refuge chambers in the world at present, and are considered the leaders in the development and design of refuge chamber. Currently having 80% of the refuge chamber market within Australasia and supplying some of the world largest mining and tunneling companies in Europe Canada and Sweden. We have designed and developed the Carbon monoxide scrubbing system for endogenously produce CO from occupants within the refuge chamber and have set the standard for our competitors to follow. Our company has been extensively involved with the Department of Industry and Resources in their refuge chamber guideline for metalliferous mine in Western Australia and we are the only manufacturer of refuge

chambers with European CE certification. Our clients are our most important asset and we believe in the ongoing development of our refuge chambers to ensure that we meet and exceed any standard set by regulatory bodies and the mining industry to improve safety standards to the benefit of the client's most important asset there work force.

We pride ourselves on the knowledge that we have a proven and tested product that has been designed and developed with the input and experience of the mining industry and also the world's leaders in breathing chemical technology Molecular Products.

We believe that with the mining industry and MSHA assistance we can develop and design a product that will suit the needs of the Coal industry and help in the prevention of a tragedy such as Sago happening again.