



# Permanent Refuge Chambers

Permanent refuge solutions for underground safety zones, excavations and break/rest areas.



mineSAFE



MineARC Systems - Built for Safety.

[www.minearc.com](http://www.minearc.com)



# Company Profile

MineARC Systems is the global leader in the manufacture and supply of emergency safe refuge solutions for the mining, tunnelling, chemical processing and disaster relief industries.

With 20 years' experience, our dedication to ongoing research and development is driven by our key focus to continually offer the best and most advanced safety solutions on the market.

Our team of qualified engineers, electrical designers and technical experts form a global network across several international locations including;

- Perth, Western Australia
- Johannesburg, South Africa
- Dallas, Texas
- Santiago, Chile
- Beijing, China
- Barcelona, Spain
- Guanajuato, Mexico

This allows MineARC to provide 24 hour service and engineering support to our expanding list of clients in over 60 countries across the globe.

All MineARC Refuge Chambers and Safe Havens comply with the highest international regulations and recognised 'world's best practice' industry guidelines. Our key focus on quality control and product advancement has meant that MineARC Refuge Chambers have successfully saved lives in multiple real life industrial emergencies around the globe.

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Emergency refuge forms an integral part of an underground mine's wider Emergency Response Plan (ERP). Fires, explosions, rock-falls, flooding, and the release of smoke and other forms of toxic gas are the types of incidents that occur all too frequently, despite the high levels of planning and the safety precautions in place.

In these types of emergencies, when evacuation is no-longer safe or practical, emergency refuge is designed to provide a safe and secure 'go-to' area for personnel to gather and await extraction. MineARC Refuges have been successfully used around the world in multiple mine and tunneling emergencies to save lives.

Refuge chambers should be deployed throughout the mine to create a refuge 'network' accessible to all underground personnel whilst on foot. Depending on the country/region, regulations usually state acceptable 'safe distances' between refuge chambers.



Bureau Veritas ISO 9001:2008 Quality Management Systems



MineARC® HRM Refuge Live Risk Assessment Testing



Australian C-Tick Standards: AS4100-1998, AS3570.1-18, AS2208, AS3000, AS1716-15



Canadian Standards Association (CSA)



United States National Electrical Code (NEC) 2013/14



European CE Certified to Machinery Norms

# Permanent Safety Solutions

A permanent refuge chamber (as opposed to portable) can often prove to be a more efficient and cost effective solution for an underground mine. In particular, mines that;

- Have a large number of personnel underground at any one time,
- Have low excavation costs, and
- Where the regular movement of personnel underground remains within certain areas.

Permanent refuge chambers therefore often double as break, rest and lunch areas, capable of sheltering upwards of hundreds of personnel at any one time.

For any refuge chamber to be effective; it is essential that personnel can reach its location as quickly as possible, and can shelter from the immediate threat of fire, smoke and toxins. Although permanent refuge facilities often at times provide this first basic level of protection, how can occupants know they will be safe once they arrive, close the door and seal themselves in?

**Q** How do you control the build up of carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO) within the refuge?

**Q** How do you prevent the shelter interior from becoming too hot and humid to support life?

**Q** How do you ensure that critical life support systems continue to operate if mains electrical supply fails?

**A** CO<sub>2</sub> / CO Scrubbing System.

**A** Cooling and Dehumidifying.

**A** UPS Battery Backup System.

MineARC's unique Scrubbing System controls the build up of CO<sub>2</sub> and CO within the permanent refuge shelter. The system is capable of maintaining CO<sub>2</sub> levels to less than 1%, and CO levels below 25ppm; standard requirements for safe, breathable air.

A cooling system with a minimum capacity of 130 watts per person is recommended to mitigate the heat load of shelter occupants.

MineARC recommends an uninterruptable power supply (UPS) battery backup system in order to power critical life support equipment should mains power be disrupted or cut-off.

## Why a Permanent Refuge Chamber?

There is a growing industry trend towards large scale permanent refuge chambers. Their acceptance has been born out of multiple successful real life uses during underground emergencies such as fires and collapses.

MineARC has been at the forefront of designing new and creative ways to accommodate this movement. The protection of life in large volumes, with sometimes upwards of hundreds of miners, requires special considerations.

MineARC is the only company with the engineering capabilities to fully assess each individual customers site specific requirements as well as provide hard engineering calculations to validate any equipment selection.

It is for these reasons that companies such as Freeport-McMoRan, Glencore, Yamana Gold, Xstrata and Stillwater Mining Company have trusted MineARC to design, manufacture, and install permanent refuge chambers at their underground operations.

**Q** How do critical systems stay charged over extended periods of time?

**Q** What if the primary breathable air source becomes compromised?

**Q** How do you ensure the shelter is adequately sealed from the outside environment?

**Q** How do you avoid the risk of compressed airline contamination?

**A** Inverter Charging System.

**A** Secondary Oxygen (O<sub>2</sub>) Supply.

**A** Bulkhead Doors and Airlocks.

**A** Compressed Air Management System.

An inverter is required to charge the battery bank and provide AC power to critical equipment in the refuge room. MineARC engineers can specify the necessary inverter based on battery backup size.

MineARC suggests breathing grade O<sub>2</sub> cylinders as a secondary oxygen supply should the primary source fail. A third source of O<sub>2</sub> is strongly recommended, in the form of a sodium chlorate O<sub>2</sub> candle.

Access doors to a permanent refuge system must be airtight, in order to ensure the internal environment is safe from breathing contaminants. MineARC Airlocks are installed to ensure no gases are transferred during entry.

MineARC recommends adequate filtration for compressed air entering the refuge room. The Compressed Air Management System performs continual gas toxicity monitoring, whilst filtering the air to ensure it is breathable.

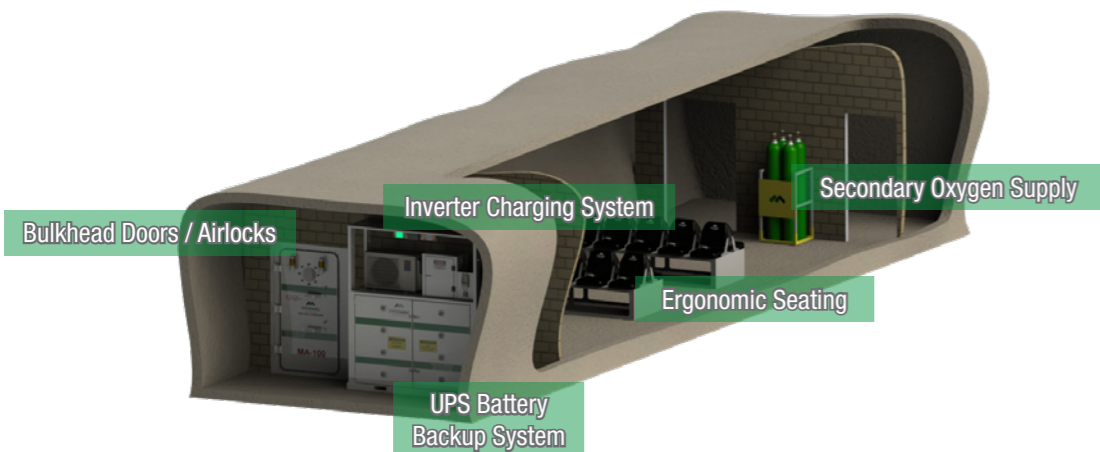
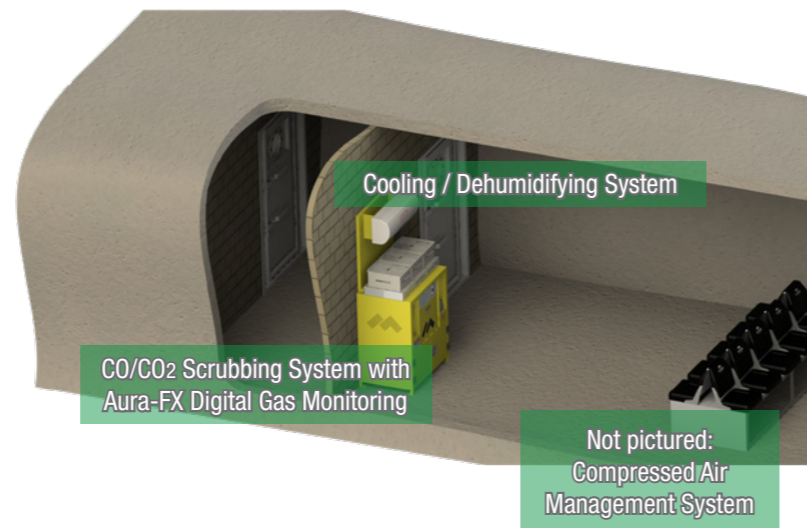
# Permanent Refuge Major Componentry

MineSAFE Permanent Refuge Rooms consist of a standard framework of recommended equipment, vital to safe operation of the shelter in an emergency.

These components include:

- CO/CO<sub>2</sub> Air Scrubbing
- Cooling / Dehumidifying System
- UPS Battery Backup
- Inverter Charging System
- Secondary Oxygen Supply
- Bulkhead Doors / Airlocks
- Compressed Air Management

MineARC engineers work closely with each site to tailor a refuge model to best suit their requirements.



Every mine is different. A number of important factors can impact the effectiveness of the refuge chamber, including;

- The industry and the ore being mined (e.g. risk of ignition, intrinsic safety requirements).
- The in-situ rock type (its temperature and thermal conductivity).
- The construction of the bulkhead.
- The layout of the refuge chamber and any secondary use.
- The ambient temperature of the mine.
- The overall volume of the enclosed space of the refuge chamber.

Based on these factors, MineARC engineers can precisely calculate;

- The required CO/CO<sub>2</sub> removal (scrubbing) capacity of the refuge chamber.
- The required compressed air flow-rate.
- The required cooling capacity.
- Secondary oxygen requirements.
- The power requirements.
- The airlock and bulkhead door requirements.
- The storage and seating requirements, if necessary.



MineARC can deliver the results in a tailored report, providing peace of mind that the equipment has been designed to meet the intended specifications.



## Also Available: EnviroLAV Toilet System

The EnviroLAV is the latest innovation in self-contained, portable toilet systems – ideal for the use in underground mining.

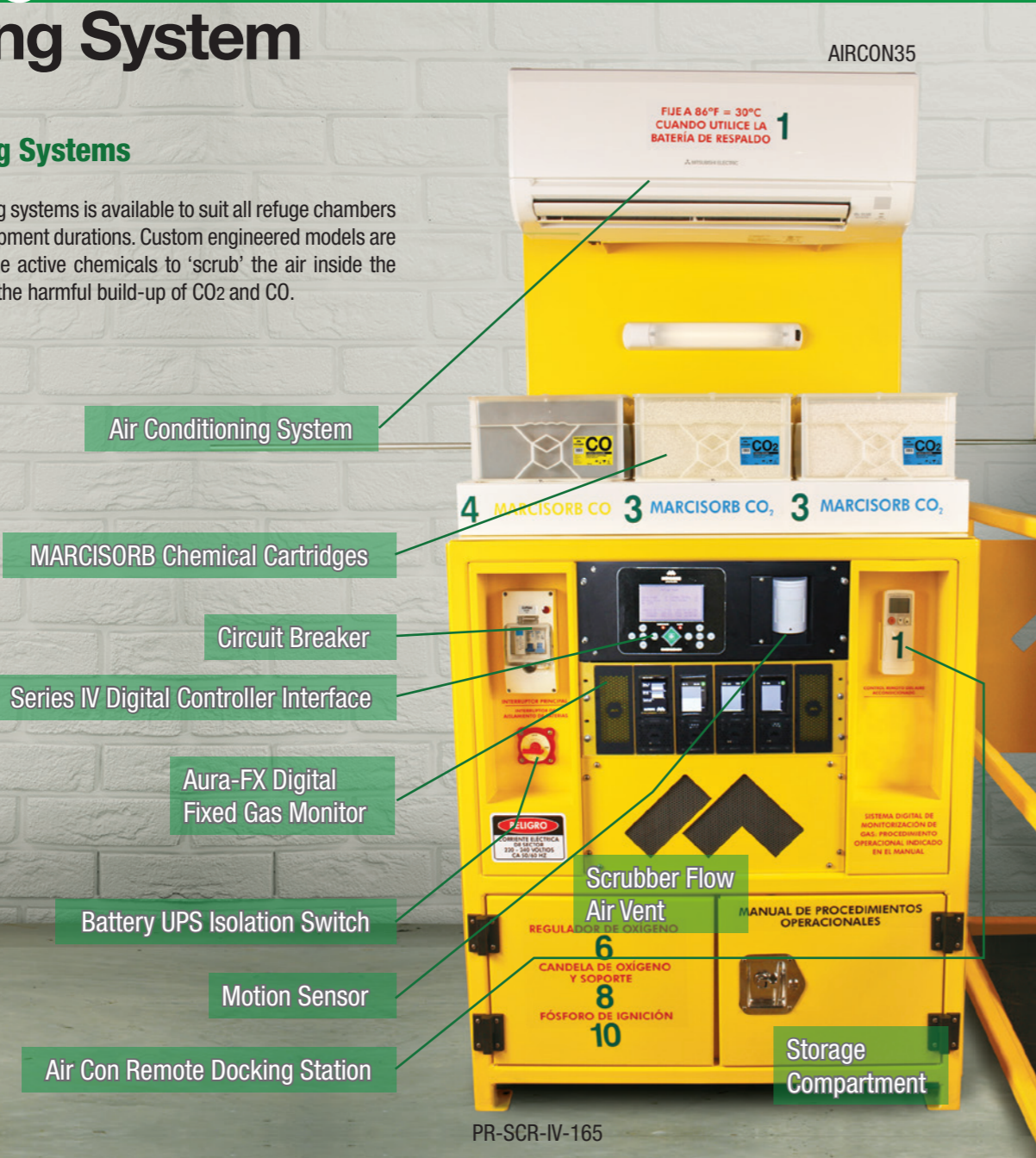
Designed to be simple to operate and maintain, the EnviroLAV is a semi-permanent structure that can be used both above and below ground wherever there is access to compressed air or electricity. The EnviroLAV requires emptying just once every 12 months, based on standard usage in optimal conditions.

For more information please visit [www.minearc.com](http://www.minearc.com)

# MineARC Scrubbing System

## CO<sub>2</sub> / CO Scrubbing Systems

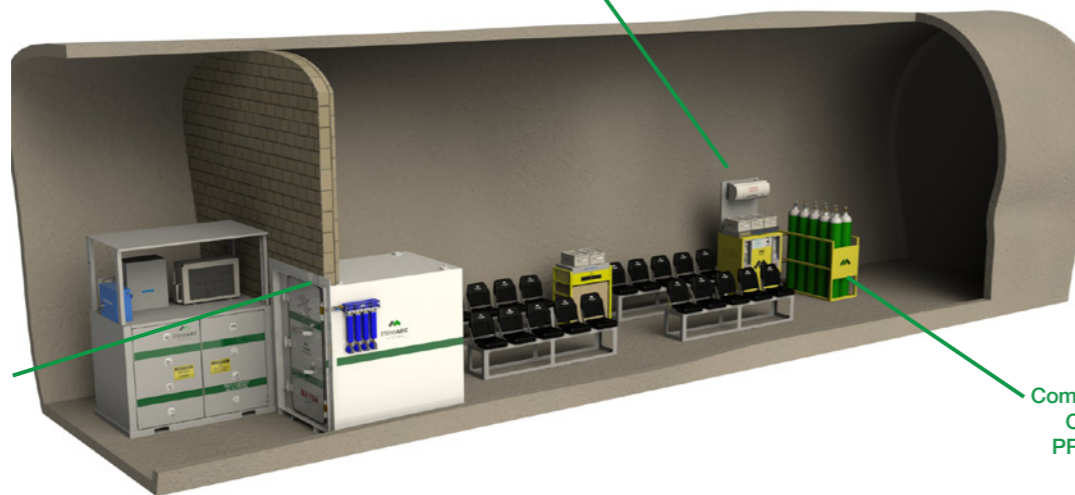
A standard range of scrubbing systems is available to suit all refuge chambers sizes, occupancies and entrapment durations. Custom engineered models are also available. All models use active chemicals to 'scrub' the air inside the refuge chamber – removing the harmful build-up of CO<sub>2</sub> and CO.



PR-SCR-IV-165

Scrubbing System  
PR-SCR-IV-165

Bulkhead Door  
PR-BD-LH



Compressed Oxygen  
Cylinder Rack  
PR-SCR-DU-300

# MineARC Scrubbing System and Air Conditioning

## SERIES IV SCRUBBERS

Remote Monitoring, Air Conditioning, iVAN, Self-Test Function, 4-20mA Current Monitoring, Aura-FX

### PR-SCR-IV-165

The MineARC Series IV Scrubber is the "Control Unit" of an expandable scrubbing system that is capable of providing CO and CO<sub>2</sub> scrubbing while also providing cooling/heating to large scale sealed environments.

Carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO) are expired by the occupants as part of their normal breathing activity. Carbon monoxide can also enter the main chamber via the compressed air intake (if it becomes compromised), and as occupants enter and/or exit the refuge chamber.

In high enough concentrations, both CO<sub>2</sub> and CO can cause serious injury, leading to a loss of consciousness and eventually, death. CO<sub>2</sub> / CO removal is therefore a vital necessity for any refuge chamber, particularly if mine air has failed and/or become compromised.

The Series IV scrubber utilises the same technology found in MineARC's MineSAFE portable refuge chambers and is capable of providing gas monitoring through Aura-FX, self-diagnostics and 4-20mA monitoring.

The digital controller interface is the operational hub of the refuge shelter. From here, all power, lighting and scrubbing systems can be managed with the push of a button. Exclusive to the MineARC Series IV Control System, iVAN (Intelligent Voice Audio Navigation) represents a breakthrough in safe-refuge technology. iVAN is an on-board navigation assistant that guides occupants through operational procedures.



For larger permanent chambers with increased air space and higher intended occupancies, multiple scrubbing systems may be required to remove the excess CO<sub>2</sub> and/or CO.

### PR-SCR-DU-150

Optional 150 CFM "Drone Scrubbing Unit" designed to be used in conjunction with the Series IV Scrubber to provide increased scrubbing potential. Up to (4) drones can be linked to a single Series IV 'Control Unit'.



### PR-SCR-DU-300

Optional 300 CFM "Drone Scrubbing Unit" designed to be used in conjunction with the Series IV Scrubber to provide increased scrubbing potential. Up to (2) drones can be linked to a single Series IV 'Control Unit'.



## Air Conditioning Systems

Air conditioning is vital to combat the potentially fatal effects of heat stress inside an occupied refuge chamber. A continuous buildup of heat is caused by the occupant's own metabolic activity, scrubbing processes, electrical equipment, and any ambient (external) heat affecting the refuge chamber's internal temperature.

All MineSAFE Chambers include quality reverse cycle split-system Mitsubishi Air Conditioners to both cool and dehumidify the refuge chamber. The evaporator unit is located inside the refuge chamber, and can be mounted to the Series IV Scrubbing System or remotely. Meanwhile the condenser fan is positioned outside the refuge chamber, mounted on top of the battery backup UPS or remotely.

Mitsubishi Air Conditioning systems are rated from 2.5kW to 8kW capacities depending on the cooling capacity required. For large occupancy permanent shelters, multiple units are used simultaneously (calculations performed by MineARC engineers).



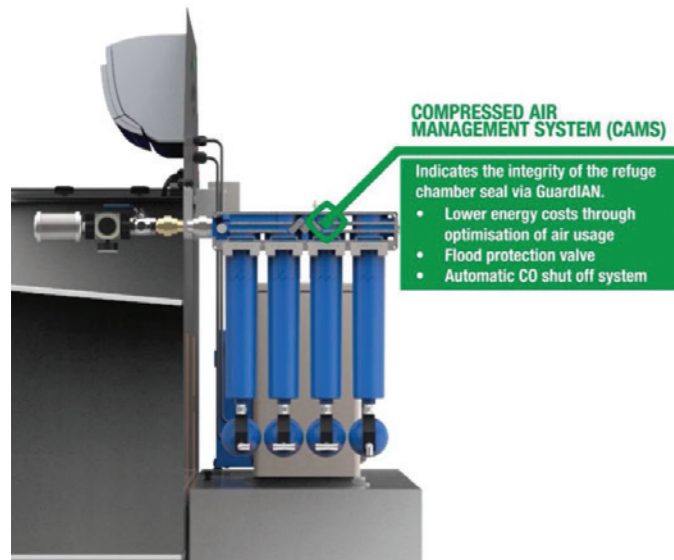
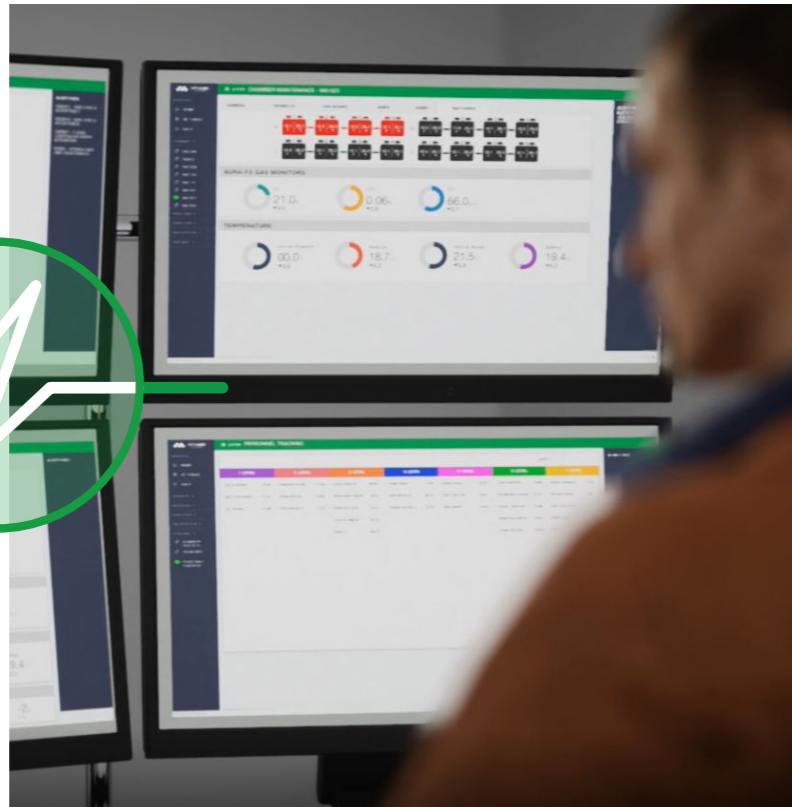
# GuardIAN Chamber Monitoring

MineARC's **GuardIAN Refuge Chamber Monitoring System** is an exciting development in refuge chamber technology. GuardIAN enables real-time monitoring; providing confidence that an operation's fleet of refuge chambers are emergency ready at all times.

GuardIAN Refuge Chamber Monitoring is an on-board system that continuously monitors all vital refuge operating systems. During standby mode GuardIAN checks for component faults and monitors refuge chamber usage or entry to the chamber.

The GuardIAN Chamber Monitoring system is hosted on an internal server within the refuge chamber so that no client software installation is required. The responsive webpage is easily accessible from any computer, tablet or smartphone and features a summary of your entire refuge chamber fleet and overall operational status, with the ability to drill down to a detailed report of each chamber.

GuardIAN Chamber Monitoring provides the added advantage of remote troubleshooting assistance by MineARC Engineers, who can login to view the chamber diagnostics dashboard with sites' permission.



**COMPRESSED AIR MANAGEMENT SYSTEM (CAMS)**  
Indicates the integrity of the refuge chamber seal via GuardIAN.

- Lower energy costs through optimisation of air usage
- Flood protection valve
- Automatic CO shut off system

## Chamber Integrity Monitoring

The Compressed Air Management System (CAMS) communicates vital information relating to the integrity of the internal refuge chamber via the GuardIAN Network.

An increase in CAMS activity would indicate a breach of the refuge chamber seal, thus sending an alert to designated personnel that the chamber is compromised.

# GuardIAN Chamber Monitoring



## UPS Battery Management

When used in conjunction with GuardIAN, the MineARC Satellite UPS System allows for real-time, remote monitoring of each individual battery. Battery faults can be identified immediately via the GuardIAN Dashboard and Alert Feed, with auto-generated event notifications sent directly to any personal device. Voltage and temperature diagnostics for each individual battery within a string can also be viewed via a graph, highlighting any fluctuations over the past 24 hours.



## Event Logging & Fault Diagnostics

MineARC's Series IV Digital Controller links directly to the GuardIAN Network, streaming real-time system data, including automated system checks, fault logging (battery, scrubber, temperature and inverter), system diagnostics, internal and external temperature measurements, and system actions such as scrubber activation.

MineARC's Aura-FX also provides real-time gas monitoring data and analysis via the GuardIAN Network dashboard.

## Live Video Monitoring and VOIP Video Phone

Internal video monitoring is provided by a remote controlled, motion activated GuardIAN IP camera. When activated, the camera will send out a live, recorded stream of the interior of the refuge chamber to the GuardIAN Network.

To assist occupants during an emergency or safety drill, chambers are also equipped with a VOIP video phone, facilitating face-to-face communication between the refuge chamber and the surface.

## Complete your network with GuardIAN Connect

GuardIAN Connect is a high speed, fit for purpose, linear access layer network, allowing the connection of the GuardIAN Nodes, Smart Lighting and Refuge Chamber to the GuardIAN Intelligence Network.

Designed specifically for an underground mining environment, GuardIAN Connect uses a single coaxial cable to carry both power and data.

# UPS Battery Back-Up

## Battery Backup (UPS)

A secure steel cabinet outside the main refuge chamber houses the refuge chamber's battery backup UPS (Uninterruptible Power Supply). The UPS is a fail safe system that can power the refuge chamber's internal life support systems for a minimum of 36 hours should mains 'mine' power become cut-off.

Cooling capacity is the major determining factors behind the size of the UPS required for a specific refuge chamber. Refuge chamber volume, ambient mine temperature and intended occupancy will all contribute towards the size of the air conditioner, and subsequently the battery backup system necessary.

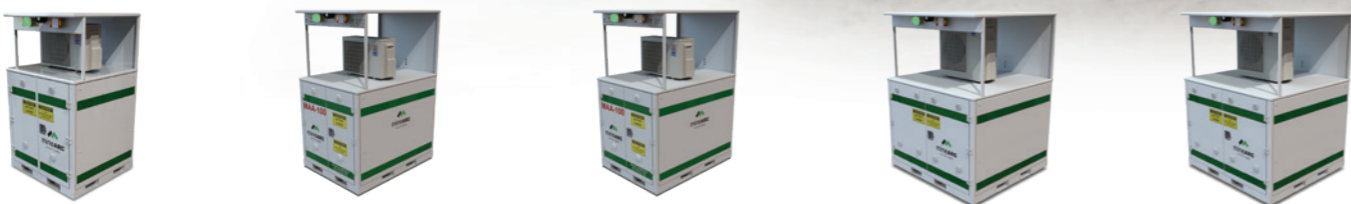
MineARC has a standard range of battery boxes to suit all refuge chamber sizes, occupancies and entrapment durations. Battery boxes can also be remotely located up to 100m (300ft) from the actual refuge chamber. Custom dimensions units are also available.



\* Battery Boxes do not include air conditioner as standard



PR-BB-12 Battery Box 12 Battery Capacity   PR-BB-16 Battery Box 16 Battery Capacity   PR-BB-20 Battery Box 20 Battery Capacity



PR-BB-24 Battery Box 24 Battery Capacity   PR-BB-36 Battery Box 36 Battery Capacity   PR-BB-44 Battery Box 44 Battery Capacity   PR-BB-56 Battery Box 56 Battery Capacity   PR-BB-CUST Battery Box Custom



## Optional: Satellite UPS System

MineARC's Satellite UPS System has been engineered specifically for use in conjunction with refuge chambers; designed to ensure batteries perform at full capacity for their expected life span and reducing manual handling-related injuries.

By ensuring atmospheric conditions are optimal, monitoring battery activity and adding electronics to the charging system, the Satellite UPS System limits all primary aspects of battery degradation and allows MineARC's high quality batteries to operate as intended.

For more information please visit [www.minearc.com/systemintelligence](http://www.minearc.com/systemintelligence)

# Secondary Oxygen Supply



Compressed Oxygen Cylinders



PR-CR-6 Cylinder Rack 6 Cylinder Capacity

PR-CR-10 Cylinder Rack 10 Cylinder Capacity

## Compressed Oxygen Cylinders

If mine air supply fails, refuge chambers should be fitted with a reliable secondary source of oxygen supply (O<sub>2</sub>). MineARC Scrubbers operate in conjunction with breathing grade O<sub>2</sub> cylinders. All scrubbers are supplied with a primary and backup oxygen regulator as well as Latex Gloves for handling.

To safely and securely house the O<sub>2</sub> cylinders, MineARC manufactures two standard configuration cylinder racks. MineARC can also supply manifold systems for larger permanent refuge shelters.



OXYCANDLE O<sub>2</sub> Candle



OXYMATCH Igniter match

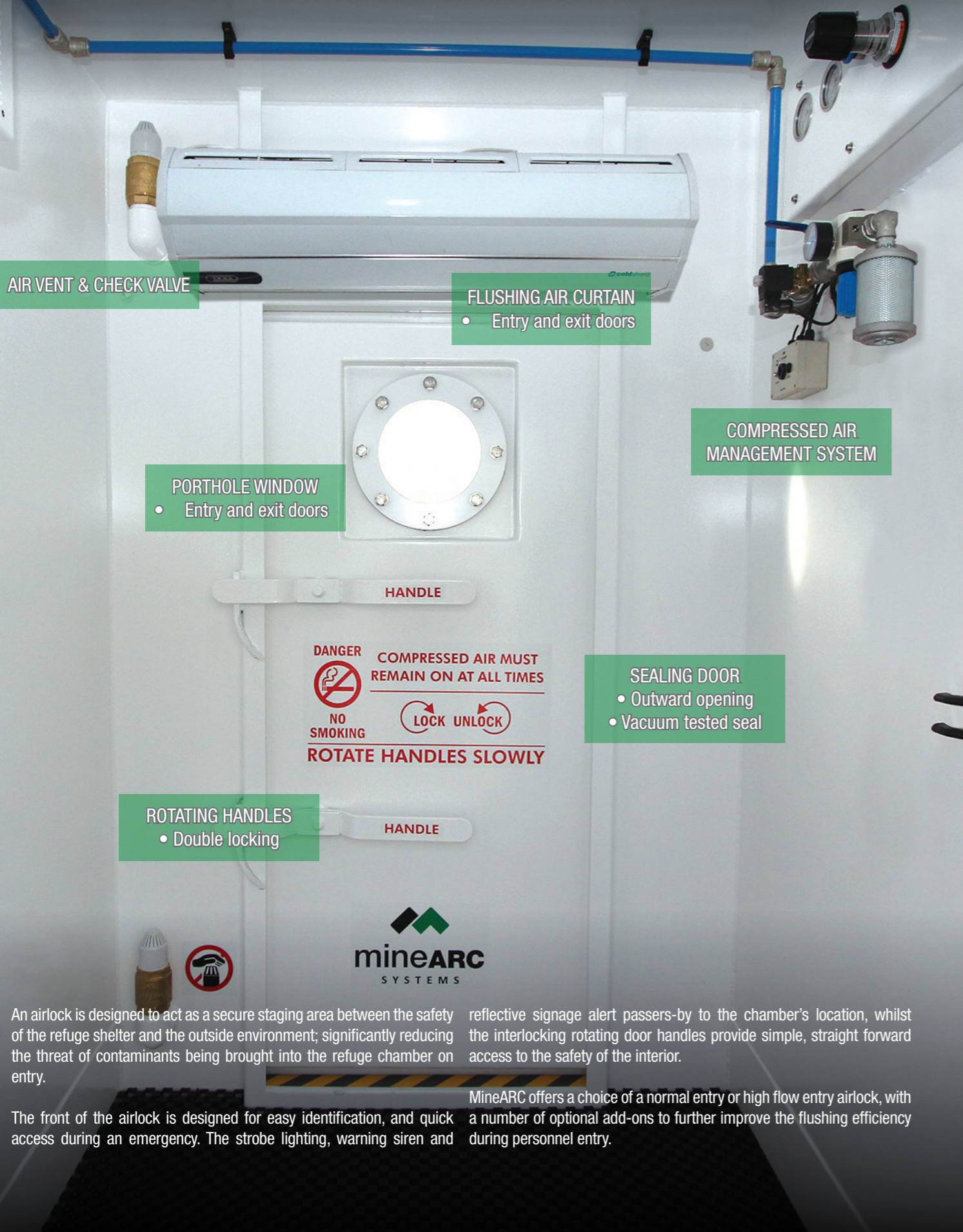
## Oxygen Candle Kit

MineARC's oxygen candle is a third source of oxygen supply should compressed air, and compressed oxygen cylinders fail and/or become exhausted. The oxygen candle is approved for military use on submarines around the world, and provides 2,600L (92ft<sup>3</sup>) of pure oxygen upon ignition.

The Oxygen Candle Kit includes an oxygen candle, oxymatch igniter, candle holder and kevlar gloves, as well as the Dangerous Goods charge.

\*Medical grade Oxygen cylinders to be provided by end user.

# Refuge Shelter Entry - Airlocks



An airlock is designed to act as a secure staging area between the safety of the refuge shelter and the outside environment; significantly reducing the threat of contaminants being brought into the refuge chamber on entry.

The front of the airlock is designed for easy identification, and quick access during an emergency. The strobe lighting, warning siren and

reflective signage alert passers-by to the chamber's location, whilst the interlocking rotating door handles provide simple, straight forward access to the safety of the interior.

MineARC offers a choice of a normal entry or high flow entry airlock, with a number of optional add-ons to further improve the flushing efficiency during personnel entry.

# Refuge Shelter Entry - Airlocks

## Flushing Racks

### Permanent Flushing Rack

Two standard configurations.

### PR-FR-06 & PR-FR-10

MineARC offers flushing racks for inclusion in pre-existing airlocks.

If mine air is lost or becomes contaminated, high pressure compressed air cylinders provide a backup supply for flushing.



## Standard Airlocks

### Passive Airlock

Two doors, six persons, no flushing.

### PR-AL

Refuge occupancy at client request.

MineARC's Passive Airlock provides protected passage into the refuge bay for up to six people at a time. MineARC doors provide an ingress factor of approximately 0.3. To avoid further contamination, an optional interlocking door system is available.



Flushing and positive pressure add-ons will further minimize the possibility of contaminants entering the refuge bay.

### Passive Airlock with BFS

Two doors, six persons, Backup Flushing System.

### PR-AL-BFS

Refuge occupancy < 40 persons

MineARC's Backup Flushing System (BFS) purges the internal airlock volume upon each entry; reducing the contaminate factor by half.

The BFS is activated once inside the airlock via a simple pneumatic push-button system, during which, controlled quantities of air are released from cylinders located within the airlock.



### Passive Airlock with PPFS

Two doors, six persons, Positive Pressure Flushing System.

### PR-AL-PPFS

Refuge occupancy > 40 persons

MineARC's Positive Pressure Flushing System (PPFS) reduces the ingress factor to approximately 0.1 with the out-flow of clean air while the airlock door is open for entry.

The PPFS is activated prior to entry via a simple electric push-button system, during which, controlled quantities of air are released from cylinders located within the airlock.



### High Flow Airlock

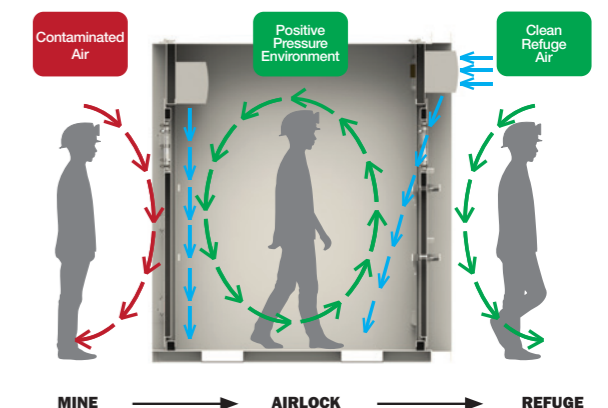
Two doors, six persons, two automatic flushing curtains for fast entry.

### PR-AL1-HF

Refuge occupancy > 80 persons

MineARC's High Flow Airlock allows for rapid entry by multiple personnel at one time. Flushing curtains are located at both the entry and exit of the airlock and are activated by sudden internal pressure changes when the airlock doors are opened.

As shown in the diagram opposite, the continual stream of air in a downwards direction forces any toxins and contaminants out of the airlock as personnel pass through. The air curtains remain active until the doors have been closed, allowing for high-flow entry by multiple personnel at one time.





# Refuge Shelter Entry - Airlocks

## Airlock Option: Compressed Air Management System (CAMS)

In the event of an emergency, during entry, the positive pressure created by CAMS ensures contaminants do not pass into the refuge bay.

Once all personnel have safely entered, the compressed air management system manually diverts to allow safely filtered mine air into the main refuge bay; providing continual, breathable compressed air flow for occupants for the duration of entrapment.

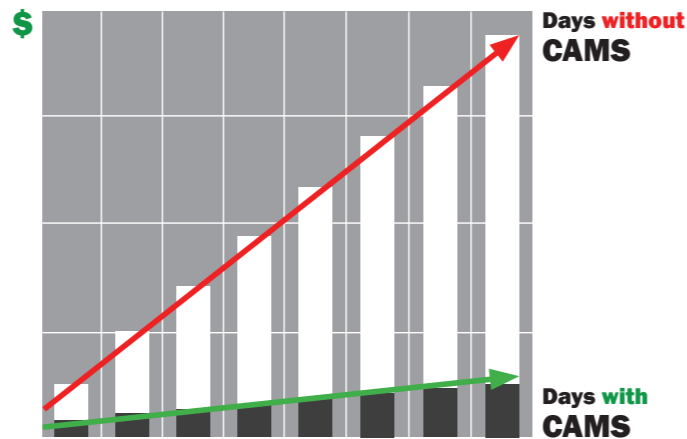
- Regulated compressed air usage, resulting in significant energy cost savings of up to 90%
- Seals the refuge bay from the ingress of harmful contaminants and toxins during entry
- Gas toxicity monitoring to prevent carbon monoxide from entering the airlock



## Regulated Compressed Air Usage

Due to the fact that refuge bays require positive pressure at all times to restrict the ingress of toxins, the cost of supplying a continual flow of compressed air to refuge bays can be considerable.

Optimising compressed air on a mine site is an important and effective way to dramatically reduce a company's operating costs. During stand-by mode, the compressed air management system of the CAMS Flushing Airlock regulates airflow into the airlock so it remains in a constant state of positive pressure. Sensors within the airlock switch the air intake on and off, emitting periodic bursts of compressed air to maintain an internal pressure of 200Pa. When measured over a year, CAMS has been shown to save up to 90% of air costs per refuge as shown on the indicative chart below.



## Four-stage Filtration

Unfiltered compressed air can be extremely hazardous to occupants' health during an emergency. Even if the airline is not compromised, hydrocarbons, oil vapor and other hazardous particles from diesel fumes and other sources common on mine sites can be drawn in through the compressed air intake and condensed to dangerous levels within the refuge. This can lead to poisoning of occupants and long-term health complications.

The CAMS Flushing Airlock provides a four stage filtration process, including water separation, pre-filter, coalescing and absorption.

## Gas Toxicity Monitoring

In the case of a mine fire, there is a risk that Carbon Monoxide can be drawn through the mine airline. CAMS is equipped with an air toxicity monitor and safety shut off valve, designed to monitor oxygen levels in the compressed air and measure displacement of oxygen by other gasses.

If O<sub>2</sub> falls below standard levels, the safety shut off system automatically activates, ensuring the safety of occupants from toxic gas ingress through the airline.

# Refuge Shelter Entry - Bulkhead Doors

MineARC manufactures a range of bulkhead doors to suit project specifications. All doors are constructed from solid steel plate, with double-locking rotating handles, rubber seals, porthole windows, and check valves to ensure a fully sealed environment. Doors can be configured either with a bulkhead mounting frame (allowing walls to be built around the door), or without a mounting frame, should a door cavity already exist.



PR-BD-RH Bulkhead Door Right Hinge



PR-BD-LH Bulkhead Door Left Hinge



PR-BD-DD Double Bulkhead Door



PR-BD-CUST Custom Bulkhead Door

# Additional Componentry

MineARC offers a range of additional componentry for Permanent Refuge Shelters. Options include gas monitoring and refuge hardware, as well as miscellaneous life support items.



### Manual Gas Monitor

Manual gas monitoring relies on chemical-filled glass tubes in conjunction with an air pump to record the levels of CO, CO<sub>2</sub> and O<sub>2</sub> in the refuge chamber. Gas readings must be taken manually by occupants every hour to ensure the atmosphere remains stable.



### Bench Seats

MineARC offers a steel bench seats with fold down marine grade cushion to seat up to five persons.



### Storage Cabinets

MineARC offers a range of storage cabinets for storage of chemicals and consumables.



### Water & Food

MineARC recommends long life water and food be incorporated into all refuge chambers.



### Sanitation

MineARC offers both chemical and waste disposal bags for human sanitation needs.



### First Aid Kits

MineARC offers complete first aid kits to meet local legislations including backboards and stretchers.



### Porthole Windows

MineARC offers porthole windows that can be integrated into existing bulkhead wall or doors for any refuge that currently lacks this vital feature.



### Pressure Relief Valves

MineARC offers pressure relief valves that can be integrated into existing bulkhead wall or doors for any refuge that currently lacks this vital feature.



### Carbon Monoxide Safety-Off

MineARC's COSO system can be integrated into any compressed air system to provide an instantaneous cut-off, should carbon monoxide levels in the airline exceed 30ppm.



### Automated Oxygen Delivery System

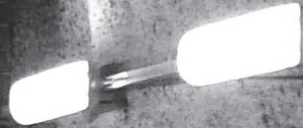
MineARC's AODS can be integrated into any oxygen delivery system to automatically maintain the chamber's internal oxygen concentration between 18.5 and 23%. Includes manual backup.



## Optional Add-Ons: Emergency Response Products

MineARC's **ZOLL AED Range** provides the best support to help save a life. Users are provided with real-time feedback for quality, depth and rate of chest compressions; providing confidence and clarity throughout the defibrillation process.

The **Rugged Oxygen Generator (ROG)** is a portable, lightweight oxygen generator that delivers 90 litres of breathable oxygen for 15 minutes. Easy-to-use and small enough to carry in a backpack, the ROG gives immediate access to a potentially life saving oxygen supply.



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