

PERFORMANCE EVALUATION OF PORTABLE REFUGE SHELTERS/CHAMBERS

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and
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I. PROJECT OVERVIEW

A. Title *Performance Evaluation of Portable Refuge Shelters/Chambers*

B. Protocol Summary

This protocol addresses the performance evaluation of mine refuge chambers for use in underground coal mines during a mine disaster. The evaluations will include injecting CO₂ and heat and humidity into the chamber while removing O₂ (and air) in order to evaluate the designed CO₂ scrubbing systems, O₂ injection systems, and temperature and humidity control systems. Length of the evaluation for each chamber will be 96 hours which is the life support duration claimed by all chamber manufacturers. Evaluation of chamber leakage (ability to maintain positive pressure) and purging (chamber and/or air lock) is also anticipated.

C. Investigators/Collaborators/Funding Sources

1. Investigators: National Institute for Occupational Safety and Health (NIOSH)
Office of Mine Safety and Health Research, Pittsburgh, PA
National Personal Protective Technology Laboratory (NPPTL), Pittsburgh, PA
Mine Safety and Health Administration (MSHA), Approval and Certification Center (A&CC), Triadelphia, WV
2. Collaborators: Chamber manufacturers (at their discretion)
ChemBio Shelter/AL Lee
Strata Products
Kennedy Metal Products
Draeger Safety Inc
Modern Mine Safety
Life Pod
Mine Safehouse
3. West Virginia Office of Miners' Health, Safety and Training
4. Funding: Emergency Supplemental Appropriations

Because of the importance of the outcome of these evaluations, and the fact that this is a scientific research evaluation, attendance at the evaluations will be limited to the collaborators listed above.

II. INTRODUCTION

A. Significance of the Problem

Three separate mining incidents in 2006 brought attention to the safety, health and training of US mine workers. The incidents, two methane explosions and one fire, required 28 workers to evacuate underground coal mines (workers located in by the disaster location) and resulted in 19 fatalities – 16 due to poisoning by inhalation. These disasters prompted the Committee on

Health, Education, Labor, and Pensions to amend the Federal Mine Safety and Health Act of 1977. The “Mine Improvement and New Emergency Response Act of 2006” (‘MINER Act’) amends the Mine Safety and Health Act of 1977 with the purpose of furthering the goals set out in the 1977 Act and enhancing worker safety in our nation’s coal mines. Generally, the act requires incident assessment and planning, the harnessing of new and emerging technologies, enhancement of research and education, improvement of safety-related procedures and protocols, and an increased enforcement and compliance to improve mine safety. Section 13 of the Act – Research Concerning Refuge Alternatives, specifies NIOSH’s responsibilities concerning refuge alternatives. The Act states that “The National Institute for Occupational Safety and Health shall provide for the conduct of research, including **field tests**, concerning the utility, practicality, survivability, and cost of various refuge alternatives in an underground coal mine environment, including commercially-available portable refuge chambers.”

Since the enactment of the MINER Act in June 2006, the state of West Virginia has taken the lead in requiring refuge shelters/chambers in the underground coal mines in that state. The West Virginia Mine Safety Technology Task Force was created to investigate and evaluate options and develop guidelines geared toward protecting the lives of miners. One specific area they were charged to investigate included the introduction of refuge chamber technology into the mines. The task force developed criteria which all West Virginia-approved chambers must satisfy. Of critical importance is the chamber’s ability to maintain an atmosphere suitable for maintaining life. This includes maintaining O₂ above 19.5%, CO₂ below 0.5%, CO below 50 ppm, and an ‘apparent-temperature’ of 95 degrees Fahrenheit. All the shelter manufacturers submitting applications to be approved in West Virginia supplied engineering calculations that “proved” their design meets these performance criteria. Many also completed short-term simulations of their scrubbing systems. But engineering calculations and small scale testing can only go so far in providing the desired level of assurance. Actual performance testing can provide the added level of confidence that the chambers will perform as required.

B. Justification

This study is a crucial component in NIOSH’s effort to fulfill its mandate under the Mine Improvement and New Emergency Response (MINER) Act to conduct research, including field tests, concerning the utility, practicality, survivability, and cost of various refuge alternatives in an underground coal environment. Performance evaluation of refuge chambers is also a critical component of verifying that it is possible for miners to survive if they are forced to seek shelter in a refuge chamber for an extended period.

C. Intended/Potential Use of Study Findings

The findings of the study will be used to verify the performance of the systems designed to provide a life-sustaining atmosphere inside of tested refuge chambers. It is hoped that the results will be used by manufacturers to modify their designs for maximum protection of entrapped miners.

D. Study Design/Locations

The basic study includes locating the refuge chamber at the Lake Lynn Facility, Fairchance, PA. The atmosphere outside the chamber will initially be approximately 55-60 deg F, which is the average underground coal mine temperature and the temperature at which all chamber manufacturers based their calculations. NIOSH researchers will enter the chamber and activate the CO₂ scrubbing and O₂ supply systems. After exiting the chamber, the CO₂, temperature and humidity simulation apparatus will be started. The simulations will be based on the rated capacity/occupancy of each individual chamber. Inside and outside atmospheric conditions will be continuously monitored. At time intervals specified in the manufacturer's operating procedure, testers will re-enter the chamber to replace the scrubbing systems (new curtains hung or canisters replaced). The CO₂ concentration at the time of scrubber system replacement will be recorded. During this reentry and exiting, the air lock protocol provided by the chamber manufacturers will be followed to minimize outside air entering the chamber for as long as the air lock purging lasts. All personnel entering the chamber will wear a suitable self-contained breathing apparatus if the atmosphere so dictates. Sampling will be conducted immediately before and after entry/exit to determine related effects. In addition, the ability for the chambers to maintain a positive pressure will be ascertained by measuring the differential pressure between the inside and outside of the chamber, monitored during the simulation. The evaluation will last 96 hours. After the atmospheric performance evaluations are completed, effectiveness of the chamber purging system (if employed by the manufacturer) and airlock purging system will be evaluated. Either a safe concentration of CO or an appropriate, non-toxic substance (smoke, tracer gas, or nitrogen) will be injected, and then purged as per chamber manufacturers' recommendations. For the chambers that utilize a CO scrubbing system, these scrubbing systems will be tested after the completion of the 96 hour evaluations.

E. Objectives

The objective of this study is to evaluate the life support systems of an underground refuge shelter/chamber chamber by demonstrating the chamber ability to provide a safe and habitable environment for its rated capacity (number of miners) over the required duration. Chambers to be tested are those that have been recently approved for use in underground coal mines in West Virginia. Shelters must provide for the basic life-support requirements of its inhabitants, including a breathable atmosphere, hydration, nutrition, hygiene, and sanitation. The performance issues to be evaluated include carbon dioxide scrubbing, oxygen generation efficiencies, internal temperature regulation, humidity control, and purging capability. The study will be conducted at the Lake Lynn Laboratory in Fairchance, PA.

F. Research Questions to be Addressed

The basic questions to be addressed by this research effort are:

1. Does the CO₂ scrubbing system, as designed by the refuge chamber manufacturer, keep the concentration below 0.5%;
2. Does the O₂ concentration remain above 19.5%?;
3. Does the heat and humidity generated by the occupants and the scrubbing system remain below the 'apparent-temperature' of 95 degrees Fahrenheit?;

4. Does the system reach a steady state, i.e. between CO₂ scrubbing system changes, does the CO₂, O₂, and ‘apparent-temperature’ remain within required levels and remain “relatively” constant?;
5. Can the 48 hour requirement of West Virginia §56-4-8 and the 96 hour requirement of MSHA PIB No. 07-03 be satisfied?; and
6. Does the purging system (airlock and/or chamber) function as designed, expelling contaminated air, to provide a breathable atmosphere after workers enter the chamber?

The study is designed to acquire the answers as to whether a given refuge chamber will ultimately perform as designed with regard to providing a life-sustaining atmosphere. This is critical if and when a refuge chamber is ever used in an actual mine emergency where escape is not possible.

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III. PROCEDURES/METHODS - DESIGN

A. Measurement/Monitoring Plan

1. Summary of Plan

The plan is to simulate the breathing of the design occupancy of a refuge chamber while monitoring the resulting interior atmosphere. The systems in the chamber designed to scrub the CO₂, provide O₂, and control temperature and humidity will be operated as per the manufacturer’s recommendations based on the number of occupants specified. The duration of each test for each individual refuge chamber will be 96 hours. This will require human intervention at designated times (manufacturers’ recommendations) to renew the CO₂ scrubbing system. If the CO₂ scrubbing system lasts for 96 hours as claimed by the manufacturer, this would satisfy both the WV §56-4-8 requirements (48 hrs) and the MSHA PIB No. 07-03 requirements (96 hrs).

NIOSH researchers will conduct the tests with the assistance of refuge chamber manufacturers/distributors. Initially, NIOSH will pretest the system of air removal, CO₂ injection, and heat and humidity delivery, along with calibration of all measurement equipment. NIOSH may also run a pre-evaluation test of the simulation scheme utilizing the chamber’s CO₂ scrubbing materials and O₂ supply system. The chamber atmosphere will be returned to normal

atmospheric conditions prior to start of the actual evaluation. NIOSH will monitor the atmosphere inside and outside the chamber, operate the atmospheric simulation equipment, deploy and change the CO₂ scrubbing materials, and pre- and post-calibration of monitoring equipment. NIOSH will perform all data analysis and report preparation.

Chamber manufacturers will be required to provide the chambers, fully stocked with CO₂ scrubbing materials, oxygen, and Grade D compressed air, and provide training for deployment for CO₂ scrubbing, O₂ supply, and purging, as well as clean-up and removal at test conclusion. Chamber manufacturers will also be asked to provide one extra, complete cycle, of CO₂ scrubbing materials, O₂ supply, Grade D compressed air, and purging air supply so that NIOSH can fine tune the evaluation methods prior to initiating the official evaluation.

2. Outcomes to be Measured and Significance

The outcome will be an assessment of the systems designed to provide a life sustaining atmosphere inside of the refuge chamber. All components including CO₂ scrubbing, O₂ supply, heat regulation and humidity control, and purging will be evaluated.

This study and outcome is significant because it can help answer the fundamental question, *Will the refuge chambers tested offer an environment that is capable of sustaining life for a 96-hour period?* Any chambers that fail to operate as designed can be modified by the manufacturer prior to placing the chambers in the mines. Reevaluation after modifications have been made may be possible if time and resources permit.

B. Stakeholder Participation

1. NIOSH

NIOSH is responsible for providing the atmospheric monitoring equipment, test site, atmospheric simulation equipment, redeployment of CO₂ scrubbing system, data collection and analysis, and report preparation.

2. Refuge Chamber Manufacturer/Supplier

Prior to the evaluation, the refuge chamber manufacturer will supply the following written documents:

1. Standard Operating Procedure (SOP) describing the chamber initial deployment procedures, operation of the CO₂ scrubbing system, O₂ supply system, and purging methods;
2. Description of the variables and calculations used for approval of the system by the state of West Virginia, i.e. CO₂ generation, O₂ consumption, and heat and humidity generation; and
3. Air requirements, flow and calculations for purging of chamber and/or airlock.

The refuge chamber manufacturers/suppliers will provide the chamber for testing, cover all shipping and transportation costs, provide the CO₂ scrubbing system and associated chemicals, provide oxygen and compressed air bottles and O₂ and compressed air as needed to purge the chamber and/or air lock, power the scrubber, and supply oxygen. Manufacturers are responsible

for providing appropriate in/out connections for data monitoring wiring, CO₂ injection, etc. Manufacturers are responsible for providing training on chamber operation utilizing the manufacturers' "Users Manual" intended to be provided with the refuge chamber. They will also be responsible for clean-up, chemical disposal, and removal of the chamber.

3. West Virginia Task Force and Mine Safety and Health Administration

Representatives from the West Virginia Task Force and MSHA, Approval and Certification Center, will participate as observers and assist with the evaluations as needed.

C. Study Time Line

The following time line is proposed:

Draft protocol completed: May 31, 2007
 Protocol peer-review completed: June 12, 2007
 Protocol revisions: June 22, 2007
 Equipment obtained and tested: June 25, 2007
 Chamber evaluations started: July 12, 2007
 Evaluations completed: October 30, 2007
 Evaluation Report completed: November 15, 2007

Chambers will be tested as they become available from the manufacturers. There are no set dates for any one particular chamber to be tested.

D. Expedited Protocol Review Request

Because of the importance of this research effort, the goal of putting into underground coal mines only refuge chambers that will protect miners, and the extreme interest in the results of this effort from the coal companies and regulatory agencies, expedited protocol review is requested.

IV. PROCEDURES/METHODS – STUDY POPULATION

A. Description and Source of Study Population

The study population (refuge chambers) consists solely of the chambers/shelters that have been approved by the State of West Virginia for use at the mining face of active sections in underground coal mines in WV. This currently is six chambers from five manufacturers. As other chambers are approved, an invitation to participate will be extended to these manufacturers as well.

B. Participant Inclusion/Exclusion Criteria

Only refuge chambers approved by the State of West Virginia will be included in the evaluations.

C. Estimated Number of Participants

At present, only 5 refuge chambers have been approved by the state of West Virginia. One additional chamber is undergoing MSHA electrical approval, which is the remaining hurdle for WV approval. This chamber will be available (final electrical approval granted) prior to the start of the evaluations.

V. PROCEDURES/METHODS – VARIABLES/INTERVENTIONS

A. Variables

Variables from test to test include the differences in refuge chamber design, operation and capacity. These differences should not have any affect on the protocol. In addition, the complex simulation scheme listed below assumes the atmosphere inside the chambers remains relatively constant throughout the evaluation. This likely is not the case and thus some mid-test adjustments may need to be made. These adjustments would include the amount of air removed based on the percent of O₂ in the chamber, then the injected air would be adjusted as well. Any adjustments made will not drastically alter the chamber atmosphere or invalidate the tests.

Another variable that will need to be addressed is the effect that entering and exiting the chamber has on the chambers atmosphere. Certainly, the important period is the first cycle of scrubbing which will have no interference from persons entering the chamber. After that first cycle, the change in chamber atmospheric conditions will be rigidly monitored before and after entering. This will allow us to make an educated determination of the effect of entering and exiting on the outcome of the simulations. In some ways this will be reflective of what occurs when entrapped workers enter and exit the chamber for various reasons such as to check for possible escape or stragglers entering the chamber late.

B. Study Instruments

1. Atmospheric Monitoring Equipment

The following equipment will be utilized to monitor the chamber air quality inside the chambers and the environment outside the refuge chambers:

- a. CD-3A analyzer including R-1 flow controller from AEI Technologies for CO₂ concentration (<http://www.aeitechnologies.com/>);
- b. S-3A analyzer including R-1 flow controller from AEI Technologies for O₂ concentration (<http://www.aeitechnologies.com/>); and
- c. S series Dew Master digital thermometer/hygrometer with flow controller from EdgeTech for temperature and relative humidity (<http://www.edgetech.com/>).

The atmospheric data will be collected and stored automatically by computer. In addition, chamber leakage (the ability of the chamber to maintain a positive pressure and prevent contaminated air from entering) will be monitored through differential pressure measurements during the simulation and/or by statically pressurizing the inside of the chamber and monitoring any bleed-off (pressure drop). Leakage will also be estimated from the exterior atmospheric

monitoring.

2. Breathing Simulation Methods

The following values were used by the chamber manufacturers seeking approval from West Virginia:

Table 1 – Values used for West Virginia approval (per occupant).

State/Chamber	CO ₂ , l/min	O ₂ , l/min	CO, ppm	Heat, Watts (BTU/hr)	Humidity, l/day	Purging Capability
WV	0.4	0.5	<50	117.24 (400)		CO to <50 ppm 3 x Chamber vol.
MSHA	0.5097	0.62297	<25			
ChemBio Shelter/AL Lee	0.5097	0.62297				
Strata Products	0.5	0.5	<50	117.24 (400)		
Kennedy Metal Products	0.5	0.62297				
Draeger Safety Inc	0.4	0.4	<50	100 (342)	1.5	
Modern Mine Safety	0.4	0.5		150		
Life Pod (NYA) ¹						
Mine Safehouse (NYA)						

¹NYA – Not yet approved.

The values that will be used during the evaluations are those found in MSHA's PIB No. 07-03. If the chambers "pass" at the MSHA level, the chambers will be suitable for acceptance as providing 96 hours of breathable air (values listed are per occupant):

- CO₂ at 0.51 liters per minute (30 liters per hour)*;
- O₂ consumption at 0.62 liters per minute (37.5 liters per hour);
- heat generation of 117.24 Watts (400 Btu/hr); and
- humidity of 1.5 liters per day.

* All volumes at standard temperature (0°C) and pressure (760 mm Hg), dry.

A manifold distribution system will be used rather than point loading of CO₂, which will better simulate the breathing of individuals. It is not necessary to simulate the actual breathing of each individual in a chamber only the metabolism of the group. This will be accomplished by either of the two following methods:

a. Simplified Simulation Scheme

The simplified simulation scheme will be employed if it is determined or all parties (NIOSH, chamber manufacturers, MSHA) agree that the introduction of oxygen has no effect on the efficiency/operation of the CO₂ scrubbing system and if it assumed that the oxygen generation method will work as designed. This scheme is as follows:

- All oxygen generated/supplied to the chamber will be piped to the outside, the quantity measured, and vented away from the chamber;
 - CO₂ will be injected into the chamber at 0.5097 liters/min times the number of occupants;
 - Heat will be generated at 400 Btu/hr/occupant using a number of electrical heaters;
- and

4. Humidity of the chambers pretest will be the relative humidity of the Grade D air after inflation or purging. Additional humidity resulting from human breathing will be introduced at a rate of 1.5 liters/day/occupant.

b. Complex Simulation Scheme

The complicated simulation scheme is designed to more closely simulate the metabolism of a chamber full of workers. It will be employed if it is determined that the simplified scheme is not sufficient to evaluate the operation of the chambers. This scheme is as follows:

1. A quantity of air will be removed from the chamber using a vacuum pump to simulate oxygen consumption. The quantity, in liters/min, will be 0.62297 multiplied by the designed chamber occupancy divided by the fraction of O₂ in the chamber. This air will be released away from the chamber so as not to influence the surrounding atmosphere;

2. Nitrogen and CO₂ will be injected into the chamber to replace the quantities of gases removed for O₂ consumption simulation;

3. CO₂ will be injected into the chamber at .8 of the O₂ removed or 0.5097 liters/min times the number of occupants;

4. Heat will be generated at 400 Btu/hr/occupant using a number of electrical heaters/light bulbs (ASHRAE 1993); and

5. Humidity of the chambers pretest will be the relative humidity of the Grade D air after inflation or purging. Additional humidity (water vapor) resulting from human breathing will be introduced at a rate of 1.5 liters/day/occupant. The moisture will be at the exhalation temperature of (91.4 deg F) and introduced uniformly throughout the chamber.

Based on the protocol review comments, the complex simulation scheme is the evaluation method that will most likely be employed.

C. Training for all Study Personnel

NIOSH will train all NIOSH engineers and technicians in the use of any monitoring equipment, atmospheric adjustment systems, and/or documentation that will be used to complete the study. The chamber manufacturers will train NIOSH engineers and technicians on the operation of all chamber systems.

D. Test Termination

Duration of the evaluation for each chamber will be 96 hours regardless of whether the CO₂ scrubbing system or O₂ delivery system is depleted, or apparent temperature exceeds 95 deg F. The intent is to let the system run its course for 96 hours, continue collecting data on the chamber atmosphere, so that a determination can be made as to the ultimate survivability within the chamber.

VI. PROCEDURES/METHODS – DATA HANDLING AND ANALYSIS

A. Data Analysis Plan

All data analysis will be done at PRL. The analyses will simply involve compiling and displaying the collected data. Tables, charts or graphs will be developed as needed to display the results of the evaluations.

B. Data to be Collected

Data to be collected includes the specific information associated with the atmospheric conditions outside the chamber:

1. Temperature (including outside chamber skin, surrounding mine surfaces, and area measurements close and distant to the chamber);
2. Relative humidity;
3. CO₂, and O₂;
4. Air velocity; and
5. Chamber leakage (ability to maintain positive pressure).

Specific information associated with the atmospheric conditions inside the chamber include:

1. CO₂ concentration (below 0.5%);
2. O₂ level (minimum 19.5%); and
3. Apparent temperature (below 95 deg Fahrenheit). Apparent temperature will be determined using a standard apparent temperature chart for the measured temperature and humidity.

All data will be collected via computer, using a software program such as LabView, stored on the hard drive and downloaded to a memory stick. Multiple sampling points positioned to capture air quality vertically and horizontally across the entire length and width inside the chamber will be used and positioned outside the chambers to delineate the heat flow from the chamber to the mine environment. At the end of each test, the amount of scrubbing material (sodalime and/or lithium hydroxide curtains) used and remaining will be ascertained. The amount of O₂ and/or compressed air used and remaining will also be gauged. This information will be supplied to chamber manufacturers for their use in modifying the chambers to satisfy both the WV requirements (48 hrs) and the MSHA PIB No. 07-03 (96 hrs).

C. Record Keeping Plan

All data will be kept at PRL. Every attempt will be made to protect all confidential and proprietary information.

VII. PROCEDURES/METHODS – HANDLING OF UNEXPECTED OR ADVERSE EVENTS

No adverse events are expected. The only possible event would be the release of an oxygen rich or carbon dioxide rich atmosphere to the mine environment. If this occurs, all electrical power will be cut and persons extracted from the immediate area. The area will be ventilated

appropriately to dilute, render harmless, and remove all hazardous concentrations. The area will be monitored until it is safe to reenter. In addition, the atmosphere outside the chambers will be monitored for toxic levels/concentrations of CO₂ and O₂.

VIII. PROCEDURES/METHODS - DISSEMINATION, NOTIFICATION, AND REPORTING OF RESULTS

A. Individual Refuge Chamber Studies

All data will be held, compiled, and disseminated by NIOSH. A report on each individual chamber evaluation will be made available to the chamber manufacturers/supplier, the West Virginia Mine Safety Technology Task Force, and MSHA Approval and Certification. After all chambers are evaluated a final comprehensive report will be generated and distributed to all interested parties. The reports will include the test conditions, the data collected, and the performance of individual chambers to provide life support. No conclusions or decisions (i.e. pass/fail) about each chamber will be made.

B. Overall Project

Where and when appropriate, tests may be combined and published and/or presented at various conferences and in peer-reviewed journals. Results of the tests will also be included in NIOSH's report to Congress on refuge alternatives research as mandated in the MINER Act.

IX. HUMAN SUBJECTS CONSIDERATIONS

No human-subject testing will be conducted at this time. A separate protocol for future human-subject testing will be developed.

X. BIBLIOGRAPHY

ASHRAE [1981]. Fundamentals Handbook. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA, pp. 19.6 and 26.25.

MINER Act [2006]. Mine Improvement and Emergency Response Act of 2006. PL 109-236 (S 2803), June 15.

West Virginia Mine Safety Technology Task Force [2006]. Mine Safety Recommendations. Report to the Director of the Office of Miners' Health, Safety and Training, May 29, 136 pp.

Mine Safety Technology and Training Commission [2006]. Improving Mine Safety Technology and Training: Establishing U.S. Global Leadership. Report to the National Mining Association, Dr. R. Larry Grayson, Chairman, Dec. 5, 193 pp.

XI. ATTACHMENTS

Attachment 1 – State of WV approved refuge chamber specifications

COMPANY	NAME	TYPE of CHAMBER	CAPACITY	CO2 SCRUBBER	O2 SUPPLY	PURGING
Strata Products	Fresh Air Bay	Inflatable	10, 16 or 35 miners	Comp. Air Powered (0.5 l/m/man), ? Soda Lime, 44 lbs, 5 to 24 hrs	Medical Grade O2 Bottles, 0.5 l/m/man	Comp. Air,
	Coal Mine Refuge Chamber	Steel	8/10, 15/16 or 20 miners	Comp. Air Powered (0.5 l/m/man), ? Soda Lime, 44 lbs, 5 to 24 hrs	Medical Grade O2 Bottles, 0.5 l/m/man	Comp. Air,
Modern Mine Safety Supply	Mine Refuge Chamber	Steel	26 miners	Battery Driven Blower, ? Soda Lime, 2 containers, every 7.0 hours	Medical Grade O2 Bottles, 0.5 l/m/man	Comp. Air, 130 cuft/min for 5 min
Draeger	Draeger Emergency Shelter	Steel	10 to 16 miners	Comp. Air Powered, Soda Lime Cartridges, 6 cartridges, every 7 to 11 hrs	Medical Grade O2 Bottles, 0.25 l/m/man	Comp. Air,
Kennedy	Kennedy Chamber	Steel	10 to 33 miners	Passive, Lithium Hydroxide Curtains, 3.65 curtains/man initially, 1.85 curtains/man after	Medical Grade O2 Bottles, 0.5 liters/min/miner	Comp. air and manifold, 3 x chamber volume
ChemBio/AL Lee	LifeShelter	Inflatable	10 to 30 miners	Comp. Air Powered, Soda Lime Cartridges, App. 4 hrs/cartridge	Medical Grade O2 Bottles, 1.32 CFH/miner	Comp. air, 2000 cuft available