West Virginia Coal Association

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2008 AUG 19 A 11: 33

August 14, 2008

Patricia W. Silvey, MSHA
US Department of Labor
Office of Standards, Regulations and Variances
1100 Wilson Boulevard, Room 2350
Arlington Va. 22209-3939

RE. RIN 1219-AB58

Dear Ms Silvey:

Attached please find comments and referenced attachments on behalf of the West Virginia Coal Association and the Coalition of Eastern Coal States to MSHA's proposed rule on "Refuge Chambers".

Additionally, we suggest that the daily examination of refuge chambers be changed from a "pre-shift" examination to an "on-shift" exam which would allow for some latitude in making the exam but ensuring that it is done on a daily basis.

We hope that you find our comments construction. If you have any questions, please give me a cal at 304/342-4153.

Sincerely,

Chris Hamilton

AB58-COMM-33

West Virginia Coal Association

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Draft Comments and Submittal of Chris Hamilton, Senior Vice President, West Virginia Coal Association, in Response to MSHA's Proposed Refuge Chamber Rule. Public Hearing -- July 31, 2008, Charleston West Virginia

Good morning. My name is Chris Hamilton, Senior Vice President, West Virginia Coal Association. The West Virginia Coal Association is a trade association comprised of coal producing companies that collectively account for nearly eighty percent (80%) of the states coal production.

Our membership also includes equipment manufacturers, a variety of mine vendors and supply companies, land companies, mine reclamation and explosive companies, mine maintenance and general service companies.

I'm also appearing today on behalf of the Eastern Coal States which is comprised of eastern mining states that collectively account for approximately 42% or 500 million tons of the nation's coal production, 80% or 62,000 of the nations miners and approximately 90% of the nations 600 underground mines.

We appreciate the opportunity to comment on MSHA's proposed refuge chamber rule.

We initially note for today's record that no other state is impacted quite the same as the state of West Virginia as it relates to the proposed rule on Refuge Chambers. First, WV is the leading underground coal producing state in the nation, averaging over 100 million tons of annual production throughout the past couple decades from approximately a third of the nation's underground mines. Secondly, and perhaps more pertinent to this rule making, **West Virginia has mandated refuge chambers over two years ago and today are nearing full implementation with over 90% of the state's 280 underground mines expecting to be equipped with shelters by the end of the year with 100% compliance expected in early 2009.**

The preceding statement underscores our heightened interest in MSHA's proposed rule and serves as the underlying basis for most if not all of our comments today. In fact it should also be noted that it was the state of West Virginia through the passage of SB 247, immediately following Sago, that provided the template for many provisions, including the one calling for "refuge chambers" subsequently found in the Miner Act which passed in the spring of 2006.

Furthermore, it was this same rationale basis combined with all the positive progress made in his home state that prompted Senator Robert C. Byrd to advance the appropriations language to expedite the deployment of shelters in all underground mines throughout the country. The Congressional record is clear and replete with Senator Byrd's quest to extend the same level of miner protection that exists in West Virginia to other states.

Let the record show that we fully embrace the work of the West Virginia Mine Safety Technology Task force in this important area and compliment them publicly today for their dedication to the task at hand, their overall competence and safety leadership. MSHA, and consequently the nation, would be better served if the agency would accept West Virginia's repeated offers to work with them in the critical area of miner safety.

With that in mind, we also support the comments and supportive data presented at this hearing by James Dean, co-chairman of the WV Mine Safety and Technology Task Force. We understand, as part of Jim's testimony, he will articulate the process and science behind the work of the Task Force. This important background bolsters our position and comments as well.

We are pleased to see that the proposed rule purports to grandfather state approved units. **It is imperative that the final rule clearly, and unconditionally accepts current state approved units, as meeting *all* requirements of MSHA's rule on refuge alternatives, especially the square footage and volume requirements found in the proposed rule and that such grandfathering extends for the life of the units.**

That is our primary concern and comment...That MSHA's final rule -- "clearly and unconditionally" accept current state approved units as meeting all requirements of MSHA's rules on refuge alternatives including the square/cubic footage and volume requirements.

The proposed rule is not as clear on this point as it needs to be and consequently, widespread confusion reigns within the industry as to the agencies intent.

The question is simple: <u>Will the units underground today that have been designed, manufactured, purchased and installed according to West Virginia's law be accepted in their current form including the capacity rating they were assigned as part of the state approval process and determined to be in compliance with MSHA's final rule?</u>

Based on the foregoing, we believe the record supports an unequivocal and unconditional acceptance of state approved units. Otherwise, the results would be extraordinarily punitive for states like West Virginia that exemplify safety leadership by moving forward in a professional manner with new safety technologies. It will also cause major disruption to our state program, fly in the face of the Congressional record and be violative of Federalism principles. Furthermore, it would effectively curb future innovation and technological advancement in miner safety on behalf of individual states. And, we are seeing a lot of innovation within the industry today.

Over the past two years, there has been considerable discussion and debate over refuge chambers...Are they good idea? Will they enhance survivability in the event of a mine fire or explosion? Do they make good sense? Do you run into the closet when the house is on fire? The debate ensues today and will continue among mining professionals into the future. But here in West Virginia, we realize that there is a time to debate, a time to argue and a time to move forward. As an industry we have elected to move forward. **It has taken endless days and countless hours to educate and recondition the thinking of everyone at the mine level that refuge shelters may enhance ones survivability if all else fails, including every imaginable means of escape. Consequently, the level of miner confidence with refuge shelters is beginning to improve which may very well be negated if MSHA doesn't unconditionally acknowledge state approved units.**

Square footage and Capacity:

Now to elaborate on a few keys points, namely the square footage and volume requirements found in the proposed rule and why similar provisions were rejected during deliberations of West Virginia's rule in favor of a more scientific based approach.

These provisions are found in §7.505(a)1 on page 34168 and discussed further on page 34157 of the preamble. We note that the WV Mine Safety Task Force considered applying minimum area per person requirements and decided to allow other factors (mainly temperature) to drive the size and implied volume.

The proposed requirement of 15 square feet and a minimum of 60 cubic feet of usable volume per person is based more on comfort rather than providing the life sustaining atmosphere for trapped miners and if implemented as currently written will unnecessarily de-rate the occupancy and in some cases preclude the use of these devices, especially in thinner seams.

As it relates to the **48 hr vs. 96 hr capacity** --

From 1940 to 1980 US Bureau of Mines reported that 127 miners survived behind barricades while 40 died. Each accident was unique and the reporting was not consistent making it difficult to draw statistical conclusions. However, of those that discussed duration, the maximum was 54 hours at the Belva No. 1 mine in 1954 and the least was 4 hours at the Pocahontas 31 mine in 1957. The *majority were in the 20-30 hour range. Based on these findings, the Task Force found a minimum duration of 48 hours to be adequate and justifiable. WV law provides for a duration of 48 hrs.*

The value of 48 hr in West Virginia's rule appears to be a reasonable value based on Table 4 on pg 22 of the 2007 Foster Miller Phase II Chapter 3 study (Attachment 6), which was commissioned by NIOSH under the MINER ACT, in which they examined a total of twelve past mining disasters where refuge stations would have had a positive impact, i.e. saved lives. Table 4 indicates that in all but one of the twelve cases that rescuers would have made contact with trapped miners within 48 hours or less. We point this out only to indicate that there is a substantial safety factor, perhaps excessive, in the present 96 hours and that as time increases, so does the complexity of sustaining trapped miners.

In addition to refuge chambers, there have been many other enhancements to mine emergency programs and rescue capabilities over the past two years. There have been a substantial increase in the number of mine rescue teams since 2006, and the response time has been cut in half. There has been a substantial increase in the number of SCSRs and distribution along escapeways. Additional lifelines, wireless communications and individual miner tracking devices installed. There has been substantial improvement in training so that miners better understand their escape options and many other improvements, which collectively will substantially reduce the miners need to barricade as well as reduce mine rescue response time.

We believe it is also important to note that prior to 2006 only a few basic tools, boards and brattice cloth for constructing barricades were required as illustrated in 30 C.F.R. §75.1100-2 (i)(1), Quantity and location of firefighting equipment - Emergency materials, require mine operators to have emergency materials readily available not exceeding 2 miles from each working section. *These emergency materials include boards, brattice cloth, nails, tools, etc. for mine emergency situations. In an emergency, these materials would be used for providing emergency barricades and for controlling/restoring ventilation controls.* This was the standard since the passage of the 1969 Mine Act (approximately 39 years).

We point out that refuge chambers represent one component, albeit an important one, of a comprehensive mine emergency plan. The state of West Virginia was and has been focused on providing a breathable atmosphere for trapped miners and believes that we should all not lose sight of that goal. We have made significant progress.

As indicated in the preamble of the proposed rules MSHA references the NIOSH report recommended values of 15 square feet of floor space unaffected by any other factors, e.g. stored items and 85 cubic feet of volume per miner. **We believe that MSHA is relying too strongly on the values cited in the NIOSH report.** The WVMSTTF reviewed the NIOSH Report on Refuge Alternatives and communicated their concerns to Mr. Kohler from NIOSH in writing (Attachment 7) and also at a meeting on May22, 2008 in Fairmont, WV. During this meeting Mr. Kohler indicated that NIOSH researchers had developed the recommendations of 15 square feet and 85 cubic feet per person from Naval and Civil Defense publications.

In follow-up with NIOSH, it appears that NIOSH reviewed a report entitled Coal Mine Rescue and Survival System, Volume I, Final Report dated September 1971 prepared by Westinghouse Electric Corporation (Attachment 8). Page 34 of the report states that:

In US Navy conducted tests of a 100 man shelter over a 14 day period, 12 square feet per man was found adequate. Civil Defense authorities state that "at least 12.5 square feet and 80 cubic feet per person are adequate for fallout shelters.

We do not believe it is not appropriate to apply this naval standard for a shelter with a capacity of 100 people for a 14 day (336 hour) period to varying numbers of occupants over 96 hours. This is using this information out of context and we are sure that it was simply an oversight on the part of NIOSH researchers.

We also believe that the Civil Defense reference was taken out of context. For example, The Civil Defense Technical Bulletin cited in the 1971 Westinghouse Report states under standards for radioactive fallout shelters "The shelter should provide for each occupant at least 12.5 square feet of floor area and 80 cubic feet of volume. " It also states prior to that statement that the shelter is being planned for two week occupancy for four to six individuals (336 hrs – 3.5 times 96 hours, which is 240 hrs longer than the proposed 96 hours). This civil defense Technical Bulletin TB 5-3 was published in May of 1958 and is entitled *Family Shelters for Protection against Radioactive Fallout* and is Attachment 9. This document was located at the health physics **MUSEUM LIBRARY .(**http://www.orau.org/ptp/Library/cdv/Tb-5-3%20%20Family%20Shelters%20for%20Protection%20Against%20Rad%20Fallout.pdf**)**

Other references to minimum square footage appear to be merely for sleeping purposes or comfort. One example would apply to sleeping on submarines. Again, in our opinion, these are taken out of context due to in this case this may apply for a time period of months in a confined space. The 1983 Foster Miller Report on the Development of Guidelines for Rescue Chambers, Volume I (Attachment 10) pg 38, under Section 3.1.1.2 entitled REQUIREMENTS for COMFORT also states "*The space requirements for persons in the shelter are* *estimated on the basis of 15 square feet per person. For 15 persons, this would necessitate at least 225 square feet or 12.5 ft length of crosscut 18 feet wide",* which in our opinion clearly shows that this is 1) for comfort and 2) is contemplated for built in place shelters rather than portable ones where space is at a premium due to ensuring that the unit remains easily transportable.

In additional support of our position, we would enter the following additional information into the record. In NIOSH's report on Refuge Alternatives comments were not included that offered explanation as to why some of the key values being evaluated exceeded levels being evaluated. This Table and the accompanying comments are submitted as Attachment 11. This information is currently present on NIOSH's webpage under Refuge Alternative Research Docket Number 125 and entitled Summary data table for survivability evaluations of refuge chambers conducted by NIOSH, Dec. 19, 2007. In our opinion, the comments accompanying the spreadsheet show that in some cases, the reasons for levels being exceeded was more a result of testing difficulty rather than product failure. Additional information in this area may be obtained by contacting the Office of Miners Health Safety and Training.

The Association recently located a standard listed for South African mines conducted by Bluhm Burton Engineering entitled *REVIEW OF BEST PRACTICES REGARDING THE USE OF REFUGE CHAMBERS IN SOUTH AFRICA Attachment (12)* dated **SEPTEMBER 2007** which in Appendix E contains a Directive from the South African Department of Mineral and Energy Affairs with an effective date of February 14, 1994. In this Directive on page 29 of the report under 3.2 it states:

Refuge Bays must be designed for the maximum number of persons in the section that it will serve, with a minimum floor area of 0.6 square meters per person.

This is an equivalent area of 6.46 square feet. On page 13 of the report it states that "*The rescue chambers can be permanent or intermediate [fixed or portable] in nature. The major difference between the two types, as reflected in the CoPs, is that permanent refuge chambers are connect to surface via a 160 mm to 200 mm borehole with a fan to force air into the refuge chamber and allow for life sustaining and rescue assistance to be entered from surface 'indefinitely'. The intermediate refuge bays however have a limited supply of fresh air and life sustaining assistance is available. The majority of intermediate refuge bays are designed to supply life sustaining assistance for 24 hours, but in some cases 8 hours has been specified. The majority of intermediate refuge bays are designed to supply life sustaining assistance for 24 hours.* It is important to note that all of the CoP (Codes of Practice) examined were for built in place shelters.

Given this information, we believe this is a more appropriate figure if MSHA believes it has to specify a specific minimum square footage – it would appear that it has worked for the South African mines since 1994 to the best of our knowledge. A less satisfactory approach might be to assume a linear relationship between this point of 6.46 square feet for 24 hours and 15 square feet for 336 hours as specified in the Civil Defense and predict the square footage value for 96 hours, which would yield 8.4 square feet which is shown graphically in Attachment 13.

We believe that all references to stored items in the proposed rule in regards to minimum square footage per person should be removed. Several emergency shelter designs have stored items located under the seats and as we understand this provision would greatly affect the current WV shelters that would as earlier stated probably be implemented by the time this proposed rule is finalized, for what we believe would serve little purpose.

We are checking with the approved shelter manufacturers in West Virginia and if followed through as proposed, the rule would require an increase, in some cases a doubling of size to accommodate the same number of miners. In other cases, some manufacturers have indicated that they would not be capable of producing thinner boxes (24 to 32 inch) inflatable shelters due to the excessive length of the tent material that would be required.

One example from Strata Products is shown in Attachment 14. This spreadsheet shows the estimated effect of applying the proposed values of 15 square feet and 60 cubic feet to the varying models of shelters that they have sold and are currently selling. If the area and volume contained in the airlock, scrubber and tube structure are subtracted out it would de-rate the designed occupancy by 37.5 to 68.8%.

This is unacceptable. From the information presented here, we believe that these proposed values are being based on information taken out of context, based on comfort rather than the goal of providing a survivable atmosphere for trapped miners and would actually endanger miners by delaying and in thinner seam mining removing the possible installation of this potential life saving technology. Further, it appears that the proposed standard ignored the South African directive of approximately 6.5 square feet.

Chamber Location:

With respect to refuge chamber location, West Virginia's law requires them to be located within 1000 feet of the face and the proposed federal rule specifies between 1000 and 2000 feet. We believe the West Virginia requirement was crafted to afford the greatest level of protection for miners. We also believe the historic data, some of which I have already quoted from, is supportive of the proposed 1000 to 2000 ft range.

So, where should refuge chambers be located on working sections? Within 1000 feet of the face? Between 1000 and 2000 feet outby? In a crosscut? Up the straight? Should they be installed in return entries or not? In West Virginia, we have petitions for site specific rulemaking under consideration that purport to have refuge chambers up to 5000 feet away from working faces.

Frankly, we believe we need more on-the-ground experience with these devices before making final judgment. We know mining by its very nature is unique. We know site specific conditions; mine layout and design, the size and complexity all drive the application of many mining laws and mining policy.

We also know that at the current time, we are close to having refuge chambers on every section in every mine in this state. We also know they are in close proximity to where they will most likely be used!

However, as with some of the other proposed requirements, if we're not careful, the unintended and negative consequences would certainly follow. It is conceivable that a mine in West Virginia will be required to install two (2) chambers; one inby 1000 to meet state law and one outby 1000 feet to compliance with federal law.

Worse yet, if for what ever reason MSHA elects to retain its proposed space and square and cubic footage requirements, and not completely grandfather West Virginia's approved units, and when the de-rating is factored into this scenario, as many as two or three units may be required in addition to the one already there.

In addition to our other recommendations, we recommend that MSHA modify it distance requirement by simply requiring refuge chambers to be within 2,000 feet of working faces.

Federalism:

As defined by Executive Order No. 13132, issued on August 4, 1999, policies of the federal government that have federalism implications are "regulations ... that have substantial direct effects on the States, on the relationships between the national government and the states or on the distribution of power and responsibilities among the various levels of government." (Executive Order No. 13132, Section 1 (a).)

We believe the proposed shelter regulation in its current form is violative of Executive Order No. 13132. Simply put, the proposed regulation impinges on West Virginia's shelter regulations and penalizes West Virginia for taking an early lead in the safety and protection of its coal miners working in the state.

Executive Order 13132 recognizes that new federal regulations should not impinge upon or eliminate state enforcement efforts where there are significant state interests. The safety of coal miners is a vital West Virginia interest.

Immediately following the Sago Mining disaster and the Aracoma mine fire in the first 19 days of January, 2006, shelters were mandated in all underground coal mines to provide a safe location for those miners who could not evacuate from a catastrophic event. West Virginia, through its regulatory process, developed standards for its shelters. Those shelters are now in place at mines throughout the state.

We call on MSHA to unconditionally grandfather West Virginia's approved units. Accordingly, we propose the following new section for inclusion into the final rule:

"All shelters approved and in place in West Virginia regulated mines or which have been ordered by July 1, 2008, shall be considered to have met the standards of this regulation if the shelters meet West Virginia state law requirements.

This change will also meet the Executive Order Section 3 requirements that federal agencies shall encourage states to develop their own policies to achieve program objectives and where possible, defer to the states to establish standards. Section 3 of the Executive Order also directs consideration of alternatives that limit the scope of national standards and preserve state prerogatives and authority. (Executive Order No. 13132, Section 3(d)(1-3))

Conclusion:

At the outset of my remarks, I indicated I was representing several mining states. We all share a fundamental objective of preserving state programs and state approved refuge shelters. It should be noted that many states have purchased refuge shelters that were approved under West Virginia law for deployment in their mines. In fact, it has been estimated that there are as many refuge chambers, approved by West Virginia, installed in other states as there are in West Virginia.

We believe this further attests to the quality of West Virginia's program, the technical and engineering capabilities of refuge chamber manufacturers, and the progressive nature of this business to provide state-of-the-art mine safety technologies and worker protection.

In closing, I'll observe there has been unprecedented criticism levied towards MSHA over the past two years than ever before in the history of the agency. That is a fact – plainly and simply. Some of it deserved, perhaps, some not.

You have the opportunity to change that perception and you could begin with this rulemaking by acknowledging the tremendous competence and expertise that exists outside the agency within the industry.

We appreciate the opportunity to comment on this proposed refuge chamber rule and welcome your involvement and partnership in future mine safety programs.

Thank You.

WEST VIRGINIA
SECRETARY OF STATE
BETTY IRELAND
ADMINISTRATIVE LAW DIVISION

Form #7

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2006 FEB -1 P 6:54

OFFICE WEST VIRGINIA
SECRETARY OF STATE

Effective Date

NOTICE OF AN EMERGENCY RULE

AGENCY: Office of Miners' Health, Safety and Training TITLE NUMBER: 56

CITE AUTHORITY: W.Va. Code 22A-2-55

EMERGENCY AMENDMENT TO AN EXISTING RULE: YES ___ NO X

IF YES, SERIES NUMBER OF RULE BEING AMENDED: ___

TITLE OF RULE BEING AMENDED: ___

IF NO, SERIES NUMBER OF RULE BEING PROPOSED: Series 2

TITLE OF RULE BEING PROPOSED: Emergency Rules Governing Protective Clothing and Equipment

THE ABOVE RULE IS BEING FILED AS AN EMERGENCY RULE TO BECOME EFFECTIVE AFTER APPROVAL BY SECRETARY OF STATE OR 42ND DAY AFTER FILING, WHICHEVER OCCURS FIRST.

THE FACTS AND CIRCUMSTANCES CONSTITUTING THE EMERGENCY ARE AS FOLLOWS:

Use additonal sheets if necessary

Authorized Signature

AB58-COMM-33-1

EMERGENCY RULE QUESTIONNAIRE

DATE: February 1, 2006

TO: LEGISLATIVE RULE-MAKING REVIEW COMMITTEE

FROM: (*Agency Name, Address & Phone No.*) Office of Miners' Health, Safety and Training,

1615 Washington Street, East, Charleston, WV 25311-2126

304-558-1425

EMERGENCY RULE TITLE: Emergency Rules Governing Protective Clothing and Equipment

1. Date of filing February 1, 2006

2. Statutory authority for promulgating emergency rule:

   W.Va. Code 22A-2-55

3. Date of filing of proposed legislative rule:

4. Does the emergency rule adopt new language or does it amend or appeal a current legislative rule? New language.

5. Has the same or similar emergency rule previously been filed and expired?

   No

6. State, with particularity, those facts and circumstances which make the emergency rule necessary for the **immediate** preservation of public peace, health, safety or welfare.

   The instant emergency rules are necessary to protect the health, safety and welfare of miners from the inherent dangers of underground mining. Given recent events the Legislature passed SB247 requiring enhanced requirements for the protective equipment and clothing worn by underground miners. Full and complete implementation of SB247 necessitates promulgation of these emergency rules.

7. If the emergency rule was promulgated in order to comply with a time limit established by the Code or federal statute or regulation, cite the Code provision, federal statute or regulation and time limit established therein.

W.Va. Code 22A-2-55(i) authorizes the Director to promulgate emergency rules to implement the provisions of SB247, which was signed into law January 26, 2006. While no precise time limit was prescribed by that bill, the public interest requires the prompt promulgation of these emergency rules.

8. State, with particularity, those facts and circumstances which make the emergency rule necessary to prevent substantial harm to the public interest.

The instant emergency rules are necessary to prevent substantial harm to the public interest. Given recent events the Legislature passed SB247 requiring enhanced requirements for the protective equipment and clothing worn by underground miners. Full and complete implementation of SB247 necessitates promulgation of these emergency rules.

EMERGENCY

WEST VIRGINIA LEGISLATIVE RULE

OFFICE OF MINERS' HEALTH, SAFETY AND TRAINING

TITLE 56

SERIES 2

EMERGENCY RULES GOVERNING PROTECTIVE CLOTHING AND EQUIPMENT

§56-2-1. General.

1.1. Scope. -- These emergency rules pertain to the implementation of provisions of W. Va. Code § 22A-2-55, relating to the regulation of protective clothing and equipment worn by persons underground by the Office of Miners' Health, Safety and Training.

1.2. Authority. -- W. Va. Code § 22A-2-55.

1.3. Filing Date. -- February 1, 2006.

1.4. Effective Date. -- ______________, 2006.

§56-2-2. Preamble.

2.1. Purpose - The primary goal of section fifty-five, article two, chapter twenty-two-a of the Code is to protect the health and safety of this State's coal miners by requiring minimum standards for the protective clothing and equipment worn by each underground miner. The purpose of these regulations is to implement the mandate of section fifty-five, article two, chapter twenty-two-a of the Code by requiring coal mine operators to provide each underground miner with certain protective equipment and by detailing the requirements for such protective equipment. In implementing such mandate, it is recognized that different types of protective equipment may be developed to satisfy the minimum requirements for protective equipment for each mine, depending upon the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and technological advances.

§56-2-3. Definitions.

3.1. Unless herein defined, all terms used in this rule shall have the same meaning as they are defined in W. Va. Code §22A-1-2 and W. Va. Code §22A-2-55.

3.2. "Code" shall mean the Code of West Virginia, 1931, as amended.

§56-2-4. Storage Caches of Additional Self-Contained Self-Rescue Devices.

4.1. In addition to providing each person underground a self-contained self-rescue device in accordance with the provisions of subdivision (1), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code, the operator shall also provide caches of additional self-contained self-rescue devices throughout the mine in accordance with a Storage Cache Plan approved by the Director.

4.1.1. Each additional self-contained self-rescue device shall be adequate to protect a miner for one hour or longer.

4.1.2. Each cache shall be housed in a container constructed of fire retardant material or material treated with a fire retardant paint or laminate and constructed in a manner capable of protecting the self-contained self rescue devices stored therein from damage by fire.

4.2. One cache shall be placed at a readily available location in each working section of the mine.

4.2.1. Each cache placed in each working section of the mine shall contain sufficient additional self-contained self-rescue devices to provide each miner at the working section with no less than sixteen (16) additional self-contained self-rescue devices. However, subject to further scientific study and evaluation, the Director may increase the minimum number of additional self-contained self-rescue devices set forth herein if deemed necessary to maintain persons awaiting rescue underground for sustained periods of time.

4.3. Storage caches also shall be placed in readily available locations throughout the remainder of the mine as follows:

4.3.1. When the height of the coal seam is above forty-eight (48) inches, every two-thousand five hundred (2,500) feet from the point where the last working section meets the main entry up to the surface, unless the conditions in the particular mine require placement at closer intervals.

4.3.2. When the height of the coal seam is below forty-eight (48) inches, every one thousand two hundred fifty (1,250) feet from the point where the last working section meets the main entry up to the surface, unless the conditions in the particular mine require placement at closer intervals.

4.3.3. Each non-working section storage cache shall contain a number of additional self-contained self-rescue devices equal to or exceeding the total number of employees who are underground during any given working shift.

§56-2-5. Storage Cache Plan.

5.1. Within thirty (30) calendar days of the effective date of these rules and regulations, all operators of all mines shall submit a Storage Cache Plan and have such plan approved by the Director. The design, development, submission, and implementation of the Storage Cache Plan shall be the responsibility of the operator of each mine.

5.2. Within thirty (30) calendar days after submission of the initial Storage Cache Plan, the Director shall either approve the plan as submitted, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

5.3. In developing the initial Storage Cache Plan, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine the operator deems relevant to the development of the Storage Cache Plan.

5.4. The Storage Cache Plan shall include the following:

5.4.1. The size and physical features of the mine;

5.4.2. The minimum number of persons underground during each working shift;

5.4.3. The proposed location of the various storage caches in relation to persons underground; and

5.4.4. A schedule of compliance, which shall include:

a. a narrative description of how the operator will achieve compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code.

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when the implementation of the proposed plan will be complete.

5.4.5. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

5.5. Each operator shall submit as attachments to its Storage

Cache Plan the following:

5.5.1. A statement that the analysis and evaluation required by section 5.3 of these rules and regulations has been completed;

5.5.2. A statement indicating the training dates for the use of the self-contained self-rescue devices; and

5.5.3. The name of the person or persons representing the operator, including his or her title, position, mailing address and telephone number, who can be contacted by the Director for all matters relating to the Storage Cache Plan and the weekly inspections of each cache.

5.6. Within thirty (30) calendar days of the Director's approval of the plan, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such number of additional self-contained self-rescue devices consistent with the operator's schedule of compliance.

5.7. At any time after the Director has approved an operator's Storage Cache Plan, the operator may submit proposed modifications or revisions to its plan along with the reasons therefor to the Director.

5.7.1. Within thirty (30) calendar days after receipt by the Director of any proposed revisions or modifications to the Storage Cache Plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

5.7.2. The Director may require modifications to a Storage Cache Plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.

5.8. If the Director, in his sole discretion, determines that an operator has failed to provide a Storage Cache Plan, has provided an inadequate Storage Cache Plan, has failed to comply with its approved Storage Cache Plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules and regulations, the Director shall issue a cessation order to the operator for the affected mine.

§56-2-6. Placement of Intrinsically Safe Battery-Powered Lights and Lifeline Cords.

6.1. Intrinsically safe battery-powered strobe lights shall be affixed to each cache of self-contained self-rescue devices and shall be capable of automatic activation in the event of an emergency.

6.1.1. All intrinsically safe battery-powered strobe lights affixed to each cache of self-contained self-rescue devices shall be approved by MSHA and maintained in accordance with applicable MSHA requirements.

6.2. A luminescent sign with the words "SELF-RESCUER" or "SELF-RESCUERS" shall be conspicuously posted at each such cache and luminescent direction signs shall be posted leading to each cache.

6.3. Lifeline cords shall be attached to each cache from the last open crosscut to the surface and must:

6.3.1. be made of durable material;

6.3.2. be marked with reflective material every twenty-five (25) feet;

6.3.3. be located in such a manner for miners to use effectively to escape; and

6.3.4. have directional indicators signifying the route of escape placed at intervals not exceeding one hundred (100) feet.

6.4. The operator shall conduct weekly inspections of each cache of additional self-contained self-rescue devices, the affixed strobe lights, and each lifeline cord or other similar device to ensure that each will function properly in the event of an emergency.

§56-2-7. Wireless Emergency Communication Devices.

7.1. A wireless emergency communication device approved by the Director shall be worn by each person underground and shall be provided by the operator.

7.1.1. Within thirty (30) calendar days of the effective date of these rules and regulations, the Director shall notify all operators of the wireless emergency communications devices approved by the Director to be used by each person underground pursuant to subdivision one, subsection (g), section fifty-five, article two, chapter twenty two-a of the Code.

7.1.2. The wireless emergency communication devices approved by the Director must be capable of receiving emergency communications from the surface at any location throughout the mine.

7.1.3. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

7.1.4. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

7.2. All wireless emergency communication devices approved by the Director shall have received prior approval by MSHA and be maintained in accordance with applicable MSHA requirements.

7.3. Within thirty (30) calendar days of the Director giving notice of the approved wireless emergency communications devices, all operators shall submit to the Director a schedule of compliance.

7.3.1. The schedule of compliance shall include:

a. a narrative description of how the operator will achieve compliance with subsection (g), section fifty-five, article two, chapter twenty-two-a of the Code;

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when full compliance will be achieved.

7.3.2. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

7.3.3. Within thirty (30) calendar days after submission of the schedule of compliance, the Director shall either approve the schedule of compliance as submitted, or shall reject and return the schedule of compliance to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the schedule of compliance is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such schedule of compliance.

7.3.4. Where applicable, the operator shall submit certified progress reports no less frequently than every thirty (30) calendar days until full compliance is achieved.

7.4. In developing the schedule of compliance, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine relevant to the provision and operation of the wireless emergency communication devices.

7.5. Within thirty (30) calendar days of the Director's approval of the operator's schedule of compliance, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such wireless emergency communication devices consistent with the operator's schedule of compliance.

7.6. If the Director, in his sole discretion, determines that an operator has failed to provide a schedule of compliance, has provided an inadequate schedule of compliance, has failed to meet its approved schedule of compliance or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subsection (g), section fifty-five, article two, chapter twenty-two-a of the Code or these rules and regulations, the Director shall issue a cessation order to the operator for the affected mine.

§56-2-8. Wireless Tracking Devices.

8.1. A wireless tracking device approved by the Director shall be worn by each person underground and shall be provided by the operator.

8.1.1. Within thirty (30) calendar days of the effective date of these rules and regulations, the Director shall notify all operators of the wireless tracking devices approved by the Director to be used by each person underground pursuant to subdivision one, subsection (h), section fifty-five, article two, chapter twenty two-a of the Code.

8.1.2. The wireless tracking devices approved by the Director must be capable of providing real-time monitoring of the physical location of each person underground.

8.1.3. No person shall discharge or in any other way discriminate against any miner based on information gathered by such wireless tracking device during non-emergency monitoring.

8.1.4. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

8.1.5. The operator shall install in or around the mine any and all equipment necessary to provide real-time emergency monitoring of the physical location of each person underground.

8.2. All wireless tracking devices approved by the Director shall have received prior approval by MSHA and be maintained in accordance with applicable MSHA requirements.

8.3. Within thirty (30) calendar days of the Director giving notice of the approved wireless tracking devices, all operators shall submit to the Director a schedule of compliance.

8.3.1. The schedule of compliance shall include:

a. a narrative description of how the operator will achieve compliance with subsection (h), section fifty-five, article two, chapter twenty-two-a of the Code;

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when full compliance will be achieved.

8.3.2. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

8.3.3. Within thirty (30) calendar days after submission of the schedule of compliance, the Director shall either approve the schedule of compliance as submitted, or shall reject and return the schedule of compliance to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the schedule of compliance is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such schedule of compliance.

8.3.4. Where applicable, the operator shall submit certified progress reports no less frequently than every thirty (30) calendar days until full compliance is achieved.

8.4. In developing the schedule of compliance, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine relevant to the provision and operation of the wireless tracking devices.

8.5. Within thirty (30) calendar days of the Director's approval of the operator's schedule of compliance, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such wireless tracking communication devices consistent with the operator's approved schedule of compliance.

8.6. If the Director, in his sole discretion, determines that an operator has failed to provide a schedule of compliance, has provided an inadequate schedule of compliance, has failed to meet its approved schedule of compliance or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subsection (h), section fifty-five, article two, chapter twenty-two-a of the Code or these rules and regulations, the Director shall issue a cessation order to the operator for the affected mine.

WEST VIRGINIA
SECRETARY OF STATE
BETTY IRELAND
ADMINISTRATIVE LAW DIVISION

Form #1

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2006 FEB 28 A 11:46

WEST VIRGINIA
STATE

NOTICE OF A PUBLIC HEARING ON A PROPOSED RULE

AGENCY: WV Office of Miners' Health, Safety and Training TITLE NUMBER: 56

RULE TYPE: Legislative CITE AUTHORITY: 22A-1-6 and 22A-1-38

AMENDMENT TO AN EXISTING RULE: YES ___ NO x

IF YES, SERIES NUMBER OF RULE BEING AMENDED: ___

TITLE OF RULE BEING AMENDED: ___

IF NO, SERIES NUMBER OF RULE BEING PROPOSED: 4

TITLE OF RULE BEING PROPOSED: Rules Governing Protective Clothing and Equipment

DATE OF PUBLIC HEARING: March 31, 2006 TIME: 9:00 a.m.

LOCATION OF PUBLIC HEARING: Mine Academy Auditorium
MSHA - National Mine Health and Safety Academy
1301 Airport Road
Beaver, WV 25813-9426

COMMENTS LIMITED TO: ORAL ___, WRITTEN ___, BOTH x

COMMENTS MAY ALSO BE MAILED TO THE FOLLOWING ADDRESS:

James M. Dean, Acting Director
WV Office of MHST
1615 Washington Street East
~~Charleston, WV 25311-2126~~

The Department requests that persons wishing to make comments at the hearing make an effort to submit written comments in order to facilitate the review of these comments.

The issues to be heard shall be limited to the proposed rule.

ATTACH A **BRIEF** SUMMARY OF YOUR PROPOSAL

James M. Dean

Authorized Signature

AB58-COMM-33-2

WEST VIRGINIA
SECRETARY OF STATE
BETTY IRELAND
ADMINISTRATIVE LAW DIVISION

Form #8

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2006 FEB 27 P 4:38

OFFICE WEST VIRGINIA
SECRETARY OF STATE

Effective Date

NOTICE OF AN EMERGENCY AMENDMENT TO AN EMERGENCY RULE

AGENCY: WV Office of Miners' Health Safety & Training TITLE NUMBER: 56

DATE EMERGENCY RULE WAS ORIGINALLY FILED: February 1, 2006

FIRST EMERGENCY AMENDMENT TO AN EXISTING RULE: YES x NO ____

SECOND EMERGENCY AMENDMENT TO AN EXISTING RULE: YES ____ NO x

DATE OF FIRST EMERGENCY AMENDMENT: ____

SERIES NUMBER OF RULE: 4

TITLE OF RULE: Rules Governing Protective Clothing and Equipment

THE ATTACHED IS AN EMERGENCY AMENDMENT TO AN EXISTING EMERGENCY RULE. THIS EMERGENCY AMENDMENT BECOMES EFFECTIVE AFTER APPROVAL BY SECRETARY OF STATE OR 42ND DAY AFTER FILING, WHICHEVER OCCURS FIRST.

THE FACTS AND CIRCUMSTANCES CONSTITUTING THE EMERGENCY AMENDMENT ARE AS FOLLOWS:

This amended rule provides for the following: the establishment of a Mine Safety Technology Task Force to provide technical assistance with the commercial availability and operational capability of rescue chambers, wireless communication and wireless tracking devices.

This rule determines the placement intervals of additional SCSRs to be used as a means to exit the mine. Rescue chambers are permitted that will provide 24 hours of breathable air.

Also, mining companies are required to submit a plan and compliance schedule for each of the requirements in the rule.

James M. Dean
Authorized Signature

Use additional sheets if necessary

EMERGENCY

WEST VIRGINIA LEGISLATIVE RULE

OFFICE OF MINERS' HEALTH, SAFETY AND TRAINING

TITLE 56

SERIES 4

EMERGENCY RULES GOVERNING PROTECTIVE CLOTHING AND EQUIPMENT

§56-4-1. General.

1.1. Scope. -- These emergency rules pertain to the implementation of provisions of W. Va. Code § 22A-2-55, relating to the regulation of protective clothing and equipment worn by persons underground by the Office of Miners' Health, Safety and Training.

1.2. Authority. -- W. Va. Code § 22A-2-55.

1.3. Filing Date. -- February __, 2006.

1.4. Effective Date. -- ______________, 2006.

§56-4-2. Preamble.

2.1. Purpose - The primary goal of section fifty-five, article two, chapter twenty-two-a of the Code is to protect the health and safety of this State's coal miners by requiring minimum standards for the protective clothing and equipment worn by each underground miner. The purpose of these rules is to implement the mandate of section fifty-five, article two, chapter twenty-two-a of the Code by requiring coal mine operators to provide each underground miner with certain protective equipment and by detailing the requirements for such protective equipment. In implementing such mandate, it is recognized that different types of protective equipment may be developed to satisfy the minimum requirements for protective equipment for each mine, depending upon the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and technological advances.

2.1.1. Exiting a mine is the primary escape procedure to be used by miners in the event of an emergency underground. Self-contained self-rescue devices ("SCSRs") are intended primarily to provide miners with breathable air while attempting to exit the mine during an emergency. The secondary purpose of SCSRs, however, is to provide a source of breathable air to miners that cannot exit a mine during an emergency and must await rescue by personnel on the surface. Emergency shelters/chambers also provide a source of breathable air for trapped miners unable to escape from the mine. Wireless emergency communication devices and wireless tracking devices are intended to assist in both directing miners out of an endangered mine and locating trapped miners awaiting rescue by personnel on the surface. In addition to the purposes stated above, the intended purpose of these rules is to establish a regulatory regime enabling the proper implementation of these technologies in West Virginia's underground mines.

§56-4-3. Definitions.

3.1. Unless herein defined, all terms used in this rule shall have the same meaning as they are defined in W. Va. Code §22A-1-2 and W. Va. Code §22A-2-55.

3.2. "Code" shall mean the Code of West Virginia, 1931, as amended.

3.3. "Director" shall herein refer to the Director of the Office of Miners' Health, Safety and Training.

§56-4-4. Mine Safety Technology Task Force.

4.1. Within seven (7) calendar days of the effective date of these rules, the Director shall establish a Mine Safety Technology Task Force to provide technical and other assistance related to the implementation of the new technological requirements set forth in section fifty-five, article two, chapter twenty-two-a of the Code. The task force shall be comprised of three persons from the major employee organization representing coal miners in this state and three persons from the major trade association representing underground coal operators in this state. All actions of the task force shall be by unanimous vote.

4.2. The task force, working in conjunction with the Director, shall immediately commence a study to determine the commercial availability and functional and operational capability of the SCSRs, emergency shelters/chambers, wireless communication devices and wireless tracking devices required hereunder. The task force shall also study issues related to the implementation, compliance and enforcement of the safety requirements contained herein. Additionally, the task force may study related safety measures, including the provision of additional surface openings and/or escapeways in lieu of or in addition to the provision of SCSRs or emergency shelters/chambers. In conducting its study, the task force shall, where possible, consult with, among others, mine engineering and mine safety experts, radiocommunication and telemetry experts and relevant state and federal regulatory personnel.

4.3. The Director, or his designee, shall preside over all meetings of the working group.

4.4. Within ninety (90) calendar days of the effective date of these rules, the task force shall provide the Director with a written report summarizing its findings regarding the commercial availability and functional and operational capability of the SCSRs, emergency shelters/chambers, wireless communication devices, wireless tracking devices and related safety measures required hereunder. The report shall also include the task force's findings and recommendations regarding implementation, compliance and enforcement of the safety requirements contained herein. The report also shall set forth the task force's recommended implementation, compliance and enforcement plans regarding the aforementioned technologies.

4.5. Prior to approving any emergency shelter/chamber, wireless communication device or wireless tracking device pursuant to the provisions of sections 5.4, 8.1, and 9.1 of these rules, respectively, the Director shall review the task force's written report and the findings set forth therein and shall consider such findings in making any approval determination.

§56-4-5. Self-Contained Self-Rescue Devices Provided for Escape from Mines.

5.1. Each person underground shall be provided a SCSR in accordance with the provisions of subdivision (1), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code. In addition, the operator shall provide caches of additional SCSRs or devices providing equivalent protection throughout the mine in accordance with a Storage Cache Plan approved by the Director.

5.1.1. Each SCSR shall be adequate to protect a miner for one (1) hour or longer: *Provided, however,* That nothing contained herein shall preclude an operator from providing each person underground with a self-rescue device or a SCSR that provides less than one (1) hour of protection that is nevertheless adequate to provide an amount of breathable air sufficient for travel to the nearest storage cache or escape facility: *Provided, further*: That the total amount of breathable air provided by the operator meets the minimum amount of three (3) hours of cumulative protection contemplated by the provisions of Section 5.1 and Section 5.2.1 of these rules, as well as the minimum protection amounts mandated by the provisions of 5.3.3 and 5.4.3.

5.1.2. Each cache shall be housed in a container constructed of fire retardant material or material treated with a fire retardant paint or laminate and constructed in a manner capable of protecting the self-contained self rescue devices stored therein from damage by fire.

5.1.3. Each operator shall train each miner in the use of the SCSRs employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year. This training shall be in addition to the annual retraining required by MSHA.

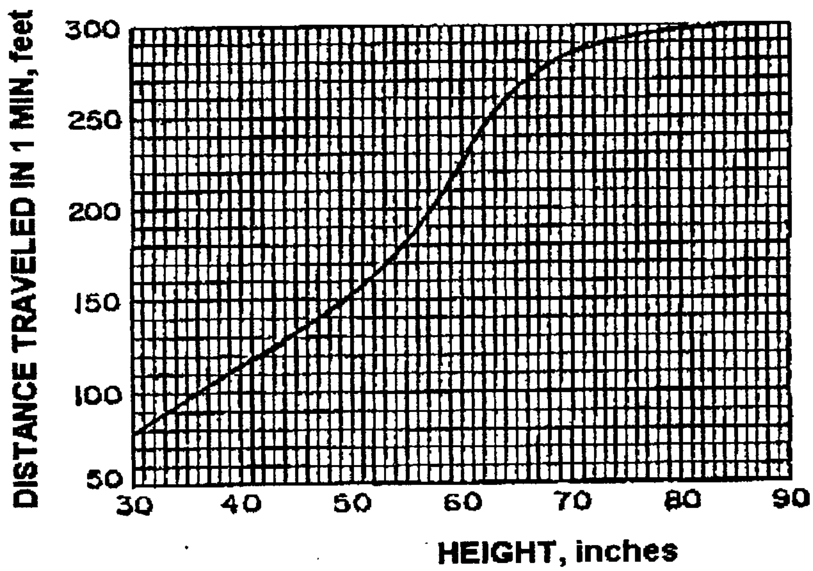
5.2. One cache shall be placed at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine. One cache shall be placed at a readily available location within five hundred (500) feet of each active construction or rehabilitation site within the mine.

5.2.1. Each cache placed at each working section and each active construction or rehabilitation site shall contain sufficient additional SCSRs to provide each miner reasonably expected to be at the working section or active construction or rehabilitation site with no less than two (2) additional SCSRs, or an equivalent amount of breathable air for escape. During crew changes involving a mantrip at a working section or an active construction or rehabilitation site, SCSRs stored on such mantrip shall satisfy the total number of SCSRs required for such personnel.

5.3. Additional storage caches shall also be placed in readily available locations throughout the remainder of the mine as follows:

5.3.1. Beginning at the storage cache located at the working section or active construction or rehabilitation site, and continuing to the surface or nearest escape facility leading to the surface, the operator shall station additional storage caches at calculated intervals that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam.

5.3.2. Said intervals shall be calculated in accordance with the following chart:



5.3.3. Each such additional cache shall contain a number of additional SCSRs equal to or exceeding the total number of employees reasonably likely to be in that area.

5.4. Emergency Shelters/Chambers for Use in the Event That Immediate Exit is not Possible.

5.4.1. An emergency shelter/chamber shall be maintained within one thousand (1000) feet of the nearest working face in each working section. Such emergency shelter/chamber shall be approved by the Director and shall be constructed and maintained in a manner prescribed by the Director.

5.4.2. Upon the Director's receipt of the written report required by section 4.4 of these rules, the Director shall review the written report and the findings set forth therein and shall consider such findings in making approval determinations regarding any emergency shelter/chamber.

5.4.3. Any emergency shelter/chamber approved by the Director shall be:

a. equipped to provide each miner at the working section with no less than twenty-four (24) hours of breathable air;

b. constructed in such a manner so as to reasonably exclude dangerous air and gases from the interior of the rescue shelter/chamber;

c. properly equipped with first aid materials;

d. equipped with sufficient amounts of food and water to sustain each miner at the working section for at least twenty-four (24) hours while awaiting rescue;

e. equipped with a device for communication with rescuers or other persons on the surface; and

f. maintained in accordance with applicable MSHA requirements.

5.4.4. As soon as practicable, the Director shall notify all operators of the emergency shelters/chambers approved for use in underground coal mines.

5.4.5. Each operator shall train each miner in the use of the approved emergency shelter/chamber employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year. This training shall be in addition to any annual retraining required by MSHA.

5.4.6. If there are no emergency shelters/chambers approved within one year of the Director's receipt of the task force's report, operators shall install in lieu of an emergency shelter/chamber, caches of SCSRs sufficient to provide each miner reasonably expected to be at the working section with no less than sixteen(16) additional SCSRs, or an equivalent amount of breathable air.

5.4.7. Sixteen (16) SCSRs may be used in lieu of an emergency shelter/chamber when mine design or layout prohibits use of such facilities.

§56-4-6. Storage Cache Plan.

6.1. Within thirty (30) calendar days of the effective date of these rules, all operators of all mines shall submit a Storage Cache Plan for approval by the Director. The design, development, submission, and implementation of the Storage Cache Plan shall be the responsibility of the operator of each mine.

6.2. Within thirty (30) calendar days after submission of the initial Storage Cache Plan, the Director shall either approve the plan as submitted, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

6.3. In developing the initial Storage Cache Plan, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine the operator deems relevant to the development of the Storage Cache Plan.

6.4. The Storage Cache Plan shall include the following:

6.4.1. The size and physical features of the mine;

6.4.2. The maximum number of persons underground during each working shift;

6.4.3. The proposed location of the various storage caches and the emergency shelter/chamber in relation to persons underground; and

6.4.4. A schedule of compliance, which shall include:

a. a narrative description of how the operator will achieve compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code.

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when the implementation of the proposed plan will be complete.

6.4.5. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

6.5. Each operator shall submit as attachments to its Storage Cache Plan the following:

6.5.1. A statement that the analysis and evaluation required by section 6.3 of these rules has been completed;

6.5.2. A statement indicating the training dates for the use of the SCSRs; and

6.5.3. The name of the person or persons representing the operator, including his or her title, position, mailing address and telephone number, who can be contacted by the Director for all matters relating to the Storage Cache Plan and the weekly inspections of each cache.

6.6. Within thirty (30) calendar days of the Director's approval of the plan, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such number of additional SCSRs consistent with the operator's schedule of compliance.

6.7. At any time after the Director has approved an operator's Storage Cache Plan, the operator may submit proposed modifications or revisions to its plan along with the reasons therefor to the Director.

6.7.1. Within thirty (30) calendar days after receipt by the Director of any proposed revisions or modifications to the

Storage Cache Plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

6.7.2. The Director may require modifications to a Storage Cache Plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.

6.7.3. Within thirty (30) calendar days of the Director notifying operators of the emergency shelters/chambers approved by the Director under these rules, the operator shall submit a revised Storage Cache Plan in accordance with the provisions of this section setting forth the type of emergency shelter/chamber to be installed pursuant to section 5.4 these rules. The revised storage cache plan shall also include a revised schedule of compliance and information regarding the emergency shelter/chamber that corresponds to the information regarding the storage caches required under this section of these rules.

6.8. If the Director, in his sole discretion, determines that an operator has failed to provide a Storage Cache Plan, has provided an inadequate Storage Cache Plan, has failed to comply with its approved Storage Cache Plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

§56-4-7. Placement of Intrinsically Safe Battery-Powered Lights and Lifeline Cords.

7.1. Intrinsically safe battery-powered strobe lights shall be affixed to each cache of SCSRs and shall operate continuously or be capable of automatic activation in the event of an emergency.

7.1.1. All intrinsically safe battery-powered strobe lights affixed to each cache of SCSRs shall be approved by MSHA and maintained in accordance with applicable MSHA requirements.

7.2. A reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" shall be conspicuously posted at each such cache and reflective direction signs shall be posted leading to each cache.

7.3. Lifeline cords installed in primary escapeways shall be attached to each cache and extend from the last permanent stopping to the surface or nearest escape facility, excluding belt and track entries, and must:

7.3.1. be made of durable material;

7.3.2. be marked with reflective material every twenty-five (25) feet;

7.3.3. be located in such a manner for miners to use effectively to escape; and

7.3.4. have directional indicators signifying the route of escape placed at intervals not exceeding one hundred (100) feet.

7.4. The operator shall conduct weekly inspections of each cache of additional SCSRs, the affixed strobe lights, and each lifeline cord or other similar device to ensure that each will function properly in the event of an emergency.

§56-4-8. Wireless Emergency Communication Devices.

8.1. A wireless emergency communication device approved by the Director shall be worn by each person underground and shall be provided by the operator.

8.1.1. As soon as practicable, the Director shall notify all operators of the wireless emergency communication devices approved by the Director for use by each person underground pursuant to subdivision one, subsection (g), section fifty-five, article two, chapter twenty two-a of the Code.

8.1.2. The wireless emergency communication devices approved by the Director must be capable of receiving emergency communications from the surface at any location throughout the mine.

8.1.3. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

8.2. All wireless emergency communication devices approved by the Director shall have received prior approval by MSHA and be maintained in accordance with applicable MSHA requirements.

8.3. Within sixty (60) calendar days of the Director giving notice of the approved wireless emergency communications devices, all operators shall submit to the Director a schedule of compliance.

8.3.1. The schedule of compliance shall include:

a. a narrative description of how the operator will achieve compliance with subsection (g), section fifty-five, article two, chapter twenty-two-a of the Code;

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when full compliance will be achieved.

8.3.2. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

8.3.3. Within thirty (30) calendar days after submission of the schedule of compliance, the Director shall either approve the schedule of compliance as submitted, or shall reject and return the schedule of compliance to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the schedule of compliance is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such schedule of compliance.

8.3.4. Where applicable, the operator shall submit certified progress reports no less frequently than every sixty (60) calendar days until full compliance is achieved.

8.4. In developing the schedule of compliance, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine and any other aspect of the particular mine relevant to the provision and operation of the wireless emergency communication devices.

8.5. Within thirty (30) calendar days of the Director's approval of the operator's schedule of compliance, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such wireless emergency communication devices consistent with the operator's schedule of compliance.

8.6. If the Director, in his sole discretion, determines that an operator has failed to provide a schedule of compliance, has provided an inadequate schedule of compliance, has failed to meet its approved schedule of compliance or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subsection (g), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

§56-4-9. Wireless Tracking Devices.

9.1. A wireless tracking device approved by the Director shall be worn by each person underground and shall be provided by the operator.

9.1.1. As soon as practicable, the Director shall notify all operators of the wireless tracking devices approved by the Director for use by each person underground pursuant to subdivision one, subsection (h), section fifty-five, article two, chapter twenty two-a of the Code.

9.1.2. The wireless tracking devices approved by the Director must be capable of providing real-time monitoring of the physical location of each person underground, which at a minimum shall mean the capability to identify the presence of each person underground in the event of an emergency.

9.1.3. No person shall discharge or in any other way discriminate against any miner based on information gathered by such wireless tracking device during non-emergency monitoring.

9.1.4. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

9.1.5. The operator shall install in or around the mine any and all equipment necessary to provide real-time emergency monitoring in accordance with the provisions of section 9.1.2 of these rules.

9.2. All wireless tracking devices approved by the Director shall have received prior approval by MSHA and be maintained in accordance with applicable MSHA requirements.

9.3. Within sixty (60) calendar days of the Director giving notice of the approved wireless tracking devices, all operators shall submit to the Director a schedule of compliance.

9.3.1. The schedule of compliance shall include:

a. a narrative description of how the operator will achieve compliance with subsection (h), section fifty-five, article two, chapter twenty-two-a of the Code;

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when full compliance will be achieved.

9.3.2. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

9.3.3. Within thirty (30) calendar days after submission of the schedule of compliance, the Director shall either approve the schedule of compliance as submitted, or shall reject and return the schedule of compliance to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the schedule of compliance is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such schedule of compliance.

9.3.4. Where applicable, the operator shall submit certified progress reports no less frequently than every sixty (60) calendar days until full compliance is achieved.

9.4. In developing the schedule of compliance, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine relevant to the provision and operation of the wireless tracking devices.

9.5. Within thirty (30) calendar days of the Director's approval of the operator's schedule of compliance, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such wireless tracking devices consistent with the operator's approved schedule of compliance.

9.6. If the Director, in his sole discretion, determines that an operator has failed to provide a schedule of compliance, has provided an inadequate schedule of compliance, has failed to meet its approved schedule of compliance or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subsection (h), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

EMERGENCY RULE QUESTIONNAIRE

DATE: February 1, 2006

TO: LEGISLATIVE RULE-MAKING REVIEW COMMITTEE

FROM: (*Agency Name, Address & Phone No.*) Office of Miners' Health, Safety and Training,

1615 Washington Street, East, Charleston, WV 25311-2126

304-558-1425

EMERGENCY RULE TITLE: Emergency Rules Governing Protective Clothing and Equipment

1. Date of filing February 1, 2006

2. Statutory authority for promulgating emergency rule:

   W Va. Code 22A-2-55

3. Date of filing of proposed legislative rule:

4. Does the emergency rule adopt new language or does it amend or appeal a current legislative rule? New language.

5. Has the same or similar emergency rule previously been filed and expired?

   No

6. State, with particularity, those facts and circumstances which make the emergency rule necessary for the **immediate** preservation of public peace, health, safety or welfare.

   The instant emergency rules are necessary to protect the health, safety and welfare of miners from the inherent dangers of underground mining. Given recent events the Legislature passed SB247 requiring enhanced requirements for the protective equipment and clothing worn by underground miners. Full and complete implementation of SB247 necessitates promulgation of these emergency rules.

APPENDIX B

FISCAL NOTE FOR PROPOSED RULES

Rule Title: 56 CSR 4 RULES GOVERNING PROTECTIVE CLOTHING AND EQUIPMENT

Type of Rule: [X] Legislative [ ] Interpretive [ ] Procedural

Agency: WV OFFICE OF MINERS HEALTH SAFETY & TRAINING

Address: 1615 WASHINGTON STREET EAST
CHARLESTON, WV 25311-2126

Phone Number: 304 558-1425 Email: jdconaway@mines.state.wv.us
caphillips@mines.state.wv.us

Fiscal Note Summary

Summarize in a clear and concise manner what impact this measure will have on costs and revenues of state government.

THE PROPOSED RULL WILL HAVE NO FINANCIAL EFFECT ON THE AGENCY'S BUDGET. ALL INSPECTION AND COMPLIANCE WILL BE ACCOMPLISHED THROUGH EXISTING AGENCY STAFF MANDATED DUTIES.

Fiscal Note Detail

Show over-all effect in Item 1 and 2 and, in Item 3, give an explanation of Breakdown by fiscal year, including long-range effect.

	FISCAL YEAR		
Effect of Proposal	Current Increase/Decrease (use "-")	Next Increase/Decrease (use "-")	Fiscal Year (Upon Full Implementation)
1. Estimated Total Cost	- 0 -	- 0 -	- 0 -
Personal Services			
Current Expenses			
Repairs & Alterations			
Assets			
Other			
2. Estimated Total Revenues			

Rule Title: 56 CSR 4 RULES GOVERNING PROTECTIVE CLOTHING AND EQUIPMENT

State of West Virginia
Joe Manchin III, Governor

WV Office Of Miners' Health, Safety & Training
Doug Conaway, Director
1615 Washington Street East • Charleston, West Virginia • 25311-2126
Telephone 304-558-1425 • Fax 304-558-1282
www.wvminesafety.org

SPECIFIC STATEMENT OF CIRCUMSTANCES WHICH REQUIRE THE RULE TO BE FILED AS EMERGENCY 56 CSR 4

In January 2006 the State of West Virginia experienced two coal mine tragedies where 14 miners were trapped and perished underground, one from an explosion and one from a belt fire.

In both cases additional breathing apparatus would have been valuable to these miners and would have given them the extra oxygen needed to survive while awaiting rescue efforts.

This rules requires the coal operator to provide sufficient additional self-contained self-rescue devices to provide each miner at the working section with no less than sixteen (16) additional self-contained self-rescue devices. It also gives the Director authority to require an increase number of the required minimum if deemed necessary.

L. Thomas Bulla, Secretary
Department of Commerce
State Capitol
Building 6, Room 525
Charleston, WV 25305-0311

State of West Virginia
Joe Manchin III
Governor

Telephone: (304) 558-2234
Toll Free: (800) 982-3386
Fax: (304) 558-1189
Email: tbulla@wvdo.org
www.boc.state.wv.us

February 24, 2006

Mr. James Mitchell Dean
Acting Director
Office of Miners' Health, Safety
and Training
1615 Washington Street East
Charleston, West Virginia 25311-2126

Dear Mr. Dean:

Upon review of your request to file an emergency legislative rule under Tittle 56, Series 4, which governs safety provisions for emergency rules governing protective clothing and equipment in the State of West Virginia, I find your proposed rule satisfactory and approve your filing of the regulations.

Sincerely,

L. Thomas Bulla
Cabinet Secretary

TB/db

WEST VIRGINIA
SECRETARY OF STATE
BETTY IRELAND
ADMINISTRATIVE LAW DIVISION

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2007 APR 26 PM 2:32

OFFICE WEST VIRGINIA
SECRETARY OF STATE

Form #6

NOTICE OF FINAL FILING AND ADOPTION OF A LEGISLATIVE RULE AUTHORIZED BY THE WEST VIRGINIA LEGISLATURE

AGENCY: WV OFFICE OF MINERS' HEALTH SAFETY & TRAINING TITLE NUMBER: 56

AMENDMENT TO AN EXISTING RULE: YES ____ NO X

IF YES, SERIES NUMBER OF RULE BEING AMENDED: ____

TITLE OF RULE BEING AMENDED: ____

IF NO, SERIES NUMBER OF RULE BEING PROPOSED: 4

TITLE OF RULE BEING PROPOSED: GOVERNING PROTECTIVE CLOTHING & EQUIPMENT

THE ABOVE RULE HAS BEEN AUTHORIZED BY THE WEST VIRGINIA LEGISLATURE.

AUTHORIZATION IS CITED IN (house or senate bill number) HB2670

SECTION 64-10-1(a), PASSED ON March 10, 2007

THIS RULE IS FILED WITH THE SECRETARY OF STATE. THIS RULE BECOMES EFFECTIVE ON THE FOLLOWING DATE: April 26, 2007

Authorized Signature

AB58-COMM-33-3

Kelley Goes, Secretary
Department of Commerce
State Capitol
Building 6, Room 525
Charleston, WV 25305-0311

State of West Virginia
Joe Manchin III
Governor

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Email: kgoes@commercewv.org
www.boc.state.wv.us

April 24, 2007

Ronald L. Wooten, Director
Office of Miners Health, Safety
and Training
1615 Washington Street East
Charleston WV 25311-2126

Dear Director Wooten:

Upon review of your request to final file legislative rule under Title 56, Series 4, "Governing Protective Clothing and Equipment" in the State of West Virginia, I find your final rule satisfactory and approve your filing of the regulations.

Sincerely,

Kelley Goes
Cabinet Secretary

KG:ks

TITLE 56
LEGISLATIVE RULE
OFFICE OF MINERS' HEALTH, SAFETY AND TRAINING

SERIES 4
GOVERNING PROTECTIVE CLOTHING AND EQUIPMENT

§56-4-1. General.

1.1. Scope. - This rule pertain to the implementation of provisions of W. Va. Code Chapter 22A Article 2-55, relating to the regulation of protective clothing and equipment worn by miners underground by the Office of Miners' Health, Safety and Training.

1.2. Authority. -- W. Va. Code Chapter 22A Article 2-55.

1.3. Filing Date. - April 26, 2007

1.4. Effective Date. - April 26, 2007

§56-4-2. Preamble.

2.1. Purpose - The primary goal of Title fifty-six Series four W. Va. Code of State Rules is to protect the health and safety of this state's coal miners by requiring minimum standards for the protective clothing and equipment worn by each underground miner. The purpose of this rule is to require coal mine operators to provide each underground miner with certain protective equipment and by detailing the requirements for such protective equipment. In implementing such mandate, it is recognized that different types of protective equipment may be developed to satisfy the minimum requirements for protective equipment for each mine, depending upon the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and technological advances.

2.2. Escape is the primary procedure to be used by miners in the event of an emergency underground. Self-contained self-rescue devices (SCSRs) are intended to isolate miners from hazardous gases and provide breathable air while attempting to escape the mine during an emergency. In the event that escape-ways are impassable emergency shelters/chambers provide a source of breathable air for miners unable to escape from the mine. Wireless emergency communication and tracking/locating devices are intended to assist in exchanging information between escaping miners and between them and those on the surface following an accident and in locating miners to aid their escape. In addition to the purposes stated above, the intended purpose of this rule is to establish a regulatory regime enabling the advancement of mine safety and health technologies and the proper implementation of these technologies in West Virginia's underground mines.

§56-4-3. Definitions.

3.1. Unless herein defined, all terms used in this rule shall have the same meaning used in W. Va. Code Chapter 22A Articles 1-2 and 2-55 and in W. Va. Code of State Rules Title 36 Series 3-13.

3.2. "Code" means the Code of West Virginia, 1931, as amended.

3.3. "Director" means to the Director of the Office of Miners' Health, Safety and Training.

3.4. "Operator" means any firm, corporation, partnership, or individual operating any coal mine or part thereof, or engaged in the construction or maintenance of any facility associated with a coal mine, and shall include any independent contractor at a coal mine.

3.5. "Independent Contractor" means any firm, corporation, partnership or individual that contracts to perform services or construction at a coal mine, excluding mine vendors, office equipment suppliers, service or delivery personnel; Provided they or their employees do not go underground.

3.6. "Self-Contained Self-Rescuer" (SCSR) means a type of closed-circuit self-contained breathing apparatus or its equivalent approved by the Mine Safety and Health Administration of the United States Department of Labor for the purpose of isolating a miner from hazardous gases and providing breathable air to aid in an escape.

3.7. "SCSR Storage Cache" means a non-combustible container constructed to withstand normal mine conditions, protect a number of SCSRs, and allow easy access for inspection of the SCSRs and easy access for miners who are escaping.

3.8. "Emergency Shelter/Chamber" means an enclosed space located within 1,000 feet of the nearest working face with all sides made from man-made materials whose function is to protect the occupants from hazardous gases and provide breathable air in the event escape is not possible.

3.9. "Emergency communications" means the transmission and reception of voice, data and/or information regarding an unexpected event requiring immediate action.

3.10. "Wireless" means allowing individual communications by a miner through a mine communication and tracking/locating system without a physical connection.

3.11. "Communication device" means equipment that is a component of an integrated mine communication and tracking/locating system for purposes of emergency communication.

3.12. "Physical location" means the position of a miner in relation to a tracking device at a known location to enhance escape and/or rescue.

3.13. "Tracking/location" means knowing the physical location of miners at the moment of an accident and as escape progresses if the tracking/location system being used is still functional.

3.14. "Tracking/locating device" means equipment that is a component of an integrated mine communication and tracking/locating system for the purpose of providing the physical location of a miner during an emergency.

3.15. "Apparent-Temperature" means a heat stress indicator that considers the effects of temperature and humidity.

§56-4-4. Mine Safety Technology Task Force.

4.1. Within seven (7) calendar days of the effective date of this rule, the Director shall establish a Mine Safety Technology Task Force to provide technical and other assistance related to the implementation of the new technological requirements set forth in W. Va. Code Chapter 22A Article 2-55. The task force shall be comprised of three miners from the major employee organization representing coal miners in this state and three miners from the major trade association representing underground coal operators in this state. All actions of the task force shall be by unanimous vote.

4.2. The task force, working in conjunction with the Director, shall study technology and technology usage issues related to the implementation, compliance and enforcement of the safety requirements covered under W. Va. CSR Title 56 Series 4. Additionally, the task force may study related safety measures as requested by the Director. In conducting its study, the task force shall, where possible, consult with, among others, mine engineering and mine safety experts, technology experts and relevant state and federal regulatory personnel.

4.3. The Director, or his designee, shall preside over all meetings of the working group.

4.4. Prior to adopting or modifying any technological safety requirement pursuant to W. Va. CSR Title 56 Series 4 the Director shall request recommendations from the task force and shall consider their written report on the subject in making any determination.

4.6. The Director shall convene the Mine Safety Technology Task Force not less than once per month.

§56-4-5. Self-Contained Self-Rescue Devices Provided for Escape from Mines.

5.1. Each miner underground shall be provided an SCSR in accordance with the provisions of W. Va. Code Chapter 22A Article 2-55(f). In addition, the operator shall provide storage caches of additional SCSRs throughout the mine in accordance with a Storage Cache Plan approved by the Director pursuant to W. Va. CSR Title 56 Series 4-6.

5.2. Each SCSR shall be approved for at least sixty (60) minutes by the Mine Safety and Health Administration (MSHA) of the United States Department of Labor: Provided, that nothing contained herein shall preclude an operator from providing each miner underground an SCSR with an MSHA approved rating less than sixty (60) minutes of breathable air that is adequate to provide for twice the travel time as defined in the chart in W. Va. CSR Title 56 series 4-6 to the nearest storage cache, as defined in W. Va. CSR Title 56 Series 4-6, or an escape facility.

5.3. Each operator shall provide training in the proper use of SCSRs in simulated emergency situations in all required SCSR training: Provided, That such simulations may be conducted on the surface. Training shall be in compliance with all manufacturers requirements and shall include but not limited to: the risks of toxic gases, manufacturer's required daily inspections, donning and starting the SCSR, limitations of the SCSR, ways to maximize duration of the unit, changing between SCSRs, communicating without removing the mouthpiece, importance and use of goggles, how to know if the device has failed and what to do if it does.

5.4. Pursuant to W. Va. Code Chapter 22A Article 1-23, operators and independent contractors shall report to the Director all SCSRs in-service by manufacturer, model, serial number, mine/contractor ID#, service dates, and results of required inspections. This information shall be submitted electronically as defined by the Director, updated quarterly and will include information on any units removed from service along with the reasons.

5.5. The Director shall compile and analyze the results of this information and distribute a report within 30 days by posting the report on the MHS&T web page, http://www.wvminesafety.org

5.6. The Director shall establish a program to periodically evaluate the quality of SCSRs in-service in West Virginia mines through collection and testing of a statistically significant number of units of differing ages and representative of models used in W. Va. mines. The results of such evaluations will be published on the MHS&T web page http://www.wvminesafety.org

§56-4-6. Self-Contained Self-Rescue Device Storage Cache Plan.

6.1. Within thirty (30) calendar days of the effective date of this rule, all operators of all mines shall submit an SCSR Storage Cache Plan for approval by the Director in accordance with W. Va. Code Chapter 22A Article 1-36. The design, development, submission, and implementation of the SCSR Storage Cache Plan shall be the responsibility of the operator of each mine.

6.2. Operators shall revise all approved SCSR storage cache plans and submit those to the Director no later than 60 days after any amendments to this rule become final.

6.3. Within thirty (30) calendar days after submission of the SCSR Storage Cache Plan, the Director shall either approve the plan as submitted, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

6.4. In developing the SCSR Storage Cache Plan, the operator shall take into consideration the needs for SCSRs in the accidents described in W. Va. Code Chapter 22A Article 2-66, the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine the operator deems relevant to the development of the Storage Cache Plan.

6.5. Each SCSR Storage Cache shall be housed in a container constructed as to protect the SCSRs from normal operational damage, be made of a material that is non-combustible, shall be easy to open during an emergency escape, shall be noted on the escape-way map, required by W. Va. Code Chapter 22A Article 2-1 and included in the mine rescue plan pursuant to W. Va. Code Chapter 22A Article 1-35(q).

6.6. One SCSR storage cache shall be placed at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine and each active construction or rehabilitation site. Distances greater than five hundred (500) feet not to exceed one thousand (1,000) feet, are permitted with approval of the Director. However, where miners are provided with personal SCSRs MSHA rated for less than sixty (60) minutes, travel to these storage caches are not to exceed five (5) minutes as determined by the height/travel time table as specified in W. Va. Code of State Rules Title 56 Series 4-6.9.2.

6.7. Each of the storage caches specified in Section 6.6 shall contain two (2) SCSRs that will provide at least sixty (60) minutes of MSHA rated duration per unit for each miner. When each miner carries an SCSR that is MSHA rated for less than sixty (60) minutes the storage cache shall hold devices equivalent to three (3) sixty (60) minute MSHA rated SCSRs for each miner. The total number of SCSRs in a stationary storage cache location will be based on the total number of miners reasonably likely to be in that area. During crew changes involving a mantrip at a working section or an active construction or rehabilitation site, a number of mantrip cached sixty (60) minute or greater MSHA rated SCSRs equal to the total number of miners reasonably likely on the mantrip shall satisfy the total number of SCSRs required for such personnel.

6.8 Operators shall ensure that storage caches required in Section 6.6 contain an escape kit containing a hammer, a tagline, a supply of chemical light sticks, and an escape-way map required by W. Va. Code Chapter 22A Article 2-1.

6.9. Additional storage caches of sixty (60) minute or longer MSHA rated SCSRs shall also be placed in readily available locations throughout the remainder of the mine as follows:

6.9.1. Beginning at the storage cache located at the working section or active construction or rehabilitation site and beltlines, pumping and bleeder areas, and continuing to the surface or nearest escape facility leading to the surface pursuant to W. Va. Code Chapter 22A Article 2-60, the operator shall station additional storage caches of sixty (60) minute or longer MSHA rated SCSRs containing a number of additional SCSRs equal to or exceeding one each for the total number of miners reasonably likely to be in that area at calculated intervals that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam and utilizing the travel times as specified in W. Va. CSR Title 56 Series 4-6-9.2. If an SCSR has an MSHA approved duration greater than sixty (60) minutes the intervals between storage caches shall be calculated at the distance traveled in one-half the approved duration.

6.9.2. Said intervals shall be calculated in accordance with the following:

Height	Travel/ Minute	Height	Travel/ Minute
28 inches	70 feet	56 inches	180 feet
32 inches	90 feet	60 inches	220 feet
36 inches	100 feet	64 inches	270 feet
40 inches	120 feet	68 inches	280 feet
44 inches	135 feet	72 inches	290 feet
48 inches	150 feet	76 inches	295 feet
52 inches	160 feet	80 inches	300 feet

6.10. The Storage Cache Plan shall include the following:

6.10.1. The size and physical features of the mine;

6.10.2. The maximum number of miners underground during each working shift;

6.10.3. The proposed location of the various storage caches and the emergency shelter/chamber in relation to miners underground; and

6.10.4.a. A schedule of compliance, which shall include:

6.10.4.a.1. A narrative description of how the operator will achieve compliance with 56 CSR 4-6.

6.10.4.a.2. A schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

6.10.4.a.3. A statement indicating when the implementation of the proposed plan will be complete.

6.11. Each operator shall submit as attachments to its SCSR Storage Cache Plan the following:

6.11.1. A statement that the analysis and evaluation required by Section 6.3 of these rules has been completed;

6.11.2. A statement indicating the training dates for the use of the SCSRs; and

6.11.3. The name of the person or persons representing the operator, including his or her title, position, mailing address and telephone number, who can be contacted by the Director for all matters relating to the Storage Cache Plan and the weekly inspections of each storage cache.

6.12. Within thirty (30) calendar days of the Director's approval of the plan, the operator shall submit to the Director a copy of any contract, purchase order, or other proof of purchase of such number of additional SCSRs consistent with the operator's schedule of compliance.

6.13. After the Director has approved an operator's SCSR Storage Cache Plan, the operator shall submit revisions to the plan at any time that changes in the operational conditions result in substantive modifications. In addition, at any time after the Director has approved an operator's Storage Cache Plan, the operator may submit proposed modifications or revisions to its plan along with the reasons therefore to the Director.

6.13.1. Within thirty (30) calendar days after receipt by the Director of any proposed revisions or modifications to the Storage Cache Plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

6.13.2. The Director may require modifications to a Storage Cache Plan at any time following the investigation of a fatal accident or serious injury, as defined by W. Va. CSR Title 36 Section 19-3.2, if such modifications are warranted by the findings of the investigation.

6.14. If the Director, in his sole discretion, determines that an operator has failed to provide an SCSR Storage Cache Plan or progress report, has provided an inadequate SCSR Storage Cache Plan or progress report, has failed to comply with its approved SCSR Storage Cache Plan or compliance schedule, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with W. Va. Code Chapter 22A Article 2-55 or this rule, the Director shall issue a cessation order to the operator for the affected mine in accordance with W. Va. Code Chapter 22A Article 1-15.

§56-4-7. Placement of Intrinsically Safe Battery-Powered Lights and Lifeline Cords.

7.1. Intrinsically safe battery-powered strobe lights approved by the Director shall be affixed to each storage cache of SCSRs and shall operate continuously or be capable of automatic activation in the event of an emergency.

7.1.1. All intrinsically safe battery-powered strobe lights affixed to each storage cache of SCSRs shall be approved by the Director and MSHA and maintained in accordance with applicable MSHA requirements.

7.1.2. Prior to approval of any MSHA certified intrinsically safe battery-powered strobe light the Director shall have prepared an independent analysis of the added risk incurred from added battery powered devices throughout the mine in the event of a catastrophic explosion.

7.1.3. The Director if determining that intrinsically safe battery-powered strobe light present an acceptable risk, shall review those rated intrinsically safe by MSHA and may approve them for use in West Virginia mines. A list of approved intrinsically safe battery-powered strobe lights shall be maintained on the MHS&T web site.

7.2. A reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" shall be conspicuously posted at each such storage cache and reflective direction signs shall be posted leading to each storage cache.

7.3. Lifeline cords installed in primary escape-ways shall be attached to each storage cache container and extend from the last permanent stopping to the surface or nearest escape facility, excluding belt and track entries, and must:

7.3.1. Be made of flame-resistant material;

7.3.2. Be marked with reflective material every twenty-five (25) feet;

7.3.3. Be located in such a manner for miners to use effectively to escape; and

7.3.4. Have directional indicators signifying the route of escape placed at intervals not exceeding one hundred (100) feet.

7.3.5. In lieu of installed lifelines in track or belt entries, markers such as floor mats with arrows, fish plate reflectors, red/green lasers shall be installed at distances not to exceed 1,000 feet or line of sight, or other equivalent devices may be used if approved by the Director.

§56-4-8. Emergency Shelters/Chambers.

8.1. An emergency shelter/chamber shall be maintained within one thousand (1,000) feet of the nearest working face in each working section. Such emergency shelter/chamber shall be approved by the Director and shall be constructed and maintained in a manner prescribed by the Director.

8.2. The Director may approve, as an alternative to a shelter/chamber, an additional surface opening located no more than 1,000 feet from the nearest working face and accurately located on escape-way maps as required in W. Va. Code Chapter 22A Article 2-1.

8.3. The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support needed to evaluate the performance of emergency shelter/chamber components/systems, and to review the effectiveness of emergency shelter/chamber plans.

8.4. The Director shall, no later than July 10, 2006, issue an open opportunity for emergency shelter/chamber providers to submit products for approval. The Director shall maintain a current list of pending and approved emergency shelter/chambers on the West Virginia MHS&T web site http://www.wvminesafety.org

8.5. Providers of emergency shelter/chamber seeking approval shall submit documentation prescribed by the Director that shall include a certification by an independent West Virginia licensed professional engineer that the proposed product meets the requirements set forth in Section 8, a description of the process used in making that determination and a certification in the following form: "I, the undersigned, herby certify that this product, to the best of my knowledge and belief, meets or exceeds all requirements set forth in W. Va. CSR Title 56 Series 4-8."

8.6. Any emergency shelter/chamber approved by the Director shall:

8.6.1. Provide a minimum of 48 hours life support (air, water, emergency medical supplies, and food) for the maximum number of miners reasonably expected on the working section;

8.6.2. Be capable of surviving an initial event with a peak overpressure of 15 psi for 3 seconds and a flash fire as defined by National Fire Protection Association standard NFPA-2113 of 300 degrees Fahrenheit for 3 seconds;

8.6.3. Be constructed such that it will be protected under normal handling and pre-event mine conditions;

8.6.4. Provide for rapidly establishing and maintaining an internal shelter atmosphere of oxygen above 19.5%, carbon dioxide below 0.5%, carbon monoxide below 50 ppm, and an apparent-temperature of 95 degrees Fahrenheit;

8.6.5. Provide the ability to monitor carbon monoxide and oxygen inside and outside the shelter/chamber;

8.6.6. Provide a means for entry and exit that maintains the integrity of the internal atmosphere;

8.6.7. Provide a means for MSHA certified intrinsically safe power if power required;

8.6.8. Provide a minimum eight quarts of water per miner;

8.6.9. Provide a minimum of 4,000 calories of food per miner;

8.6.10. Provide a means for disposal of human waste to the outside of the shelter/chamber;

8.6.11. Provide a first aid kit as defined at W. Va. Code Chapter 22A Article 2-59(3)(b) independent of the section first aid kit required by W. Va. Code Chapter 22A Article 2-59(3) and 2-60(f);

8.6.12. Have provisions for inspection of the shelter/chamber and contents;

8.6.13. Contain manufacturer recommended repair materials;

8.6.14. Provide a battery-powered occupant-activated strobe light of a model approved by the Director that is visible from the outside indicating occupancy;

8.6.15. Provide provisions for communications to the surface; and

8.6.16. Provide proof of current approval for all items and materials subject to MSHA approval.

8.7. No later than April 15, 2007 all underground mine operators shall submit an emergency shelter/chamber plan for approval by the Director in accordance with W. Va. Code Chapter 22A Article 1-36. The design, development, submission, and implementation of the shelter/chamber plan shall be the responsibility of the operator of each mine.

8.8. Within thirty (30) calendar days after submission of the emergency shelter/chamber plan, the Director shall either approve the emergency shelter/chamber plan or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

8.9. Within 15 days of approval of the emergency shelter/chamber plan by the Director, the underground mine operator shall submit as an addendum to its emergency shelter/chamber plan a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the emergency shelter/chamber and for installation and ongoing maintenance

8.10. The operator shall submit certified progress reports no less frequently than every sixty (60) calendar days until full compliance is achieved.

8.11. After the Director has approved an operator's emergency shelter/chamber plan, the operator shall submit revisions to the emergency shelter/chamber plan at any time that changes in operational conditions result in substantive modification. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the emergency shelter/chamber plan, the

Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

8.12. In developing the emergency shelter/chamber plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, advances in emergency shelter/chamber technologies and any other aspect of the particular mine the operator deems relevant to the development of the emergency shelter/chamber plan.

8.13. A copy of the approved emergency shelter/chamber plan shall be provided to the mine rescue teams providing coverage for the mine and included in the mine rescue program required by W. Va. Code Chapter 22A Article 1-35(q). Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the approved emergency shelter/chamber plan, updated versions shall be submitted to the above parties.

8.14. The proposed emergency shelter/chamber plan shall:

8.14.1. Describe the structure and operations of the emergency shelter/chamber, the surveyed location of the shelter and any necessary survey monuments for locating emergency drilling operations to the shelter/chamber and the shelter/chamber's role in emergency response;

8.14.2. Ensure that proper emergency shelter/chamber use is included in initial mine hazard training in such a manner that it is in compliance with all manufacturer's requirements and is provided yearly in addition to annual refresher training. All training shall be recorded and made available upon request;

8.14.3. Ensure weekly inspections of emergency shelters/chambers and contents shall be conducted by a certified mine foreman and/or mine examiner and recorded in weekly ventilation examination book;

8.14.4. Ensure that weekly safety meetings review the current location of applicable emergency shelters/chambers and results of the latest inspection;

8.14.5. Ensure that all opening to emergency shelters/chambers shall be equipped with easily removable tamper-proof tags such that a visual indication of unauthorized access to the emergency shelter/chamber can be detected; and

8.14.6. Ensure that the mine's communication center shall monitor any communication systems associated with the emergency shelter/chamber at all times that the mine is occupied.

8.15. If the Director, in his sole discretion, determines that an operator has failed to provide an emergency shelter/chamber plan or progress report, has provided an inadequate emergency shelter/chamber plan or progress report, has failed to comply with its approved emergency shelter/chamber plan or compliance schedule, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with W. Va. Code Chapter 22A Article 2-55 or this rule, the Director shall issue a cessation order to the operator for the affected mine.

8.16. If there are no emergency shelters/chambers approved by May 29, 2007, operators shall install in lieu of an emergency shelter/chamber, within one thousand (1,000) feet of the nearest working face in each working section, storage caches of SCSRs sufficient to provide each miner reasonably expected to be at the working section with no less than sixteen (16) additional SCSRs rated by MSHA each for a duration of sixty (60) minutes or greater, or an equivalent amount of breathable air and barricading materials described at W. Va. Code Chapter 22A Article 2-58(n).

8.17. As provided in W. Va. Code Title 22A Articles 2-55(f)(3), 2-55(g)(2), and 2-55(h)(2)any person that, without the authorization of the operator or the Director, knowingly removes or attempts to remove emergency shelter/chamber or its contents approved by the Director from the mine or mine site with the intent to permanently deprive the operator of the device or knowingly tampers with or attempts to tamper with such a device shall be deemed guilty of a felony and, upon conviction thereof, shall be imprisoned in a state correctional facility for not less than one year nor more than ten years or fined not less than ten thousand dollars nor more than one hundred thousand dollars, or both.

§56-4-9. Wireless Emergency Communication and Tracking/Locating systems.

9.1. The Director shall require, in each underground mine, an integrated communication and tracking/locating system maintained consistent with W. Va. CSR Title 36 Series 5-3.2 and a component of which shall be a communication center monitored at all times during which one or more miners are underground. A wireless emergency communication and tracking/locating device approved by the Director shall be worn by each miner underground and shall be provided by the operator.

9.2. As soon as practicable, the Director shall notify all operators of the wireless emergency communication and tracking/locating devices approved by the Director for use by each miner underground pursuant to W. Va. Code Chapter 22A Article 2-55.

9.3. The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support to evaluate the performance of individual communication/tracking devices and review the effectiveness of proposed communication/tracking plans.

9.4. The Director shall, no later than July 10, 2006, issue an open opportunity for emergency communication and tracking/locating providers to submit products for approval.

9.5. The Director shall require providers seeking approval submit documentation certified by a licensed West Virginia professional engineer that the product has been tested for functionality in West Virginia underground mines, that the product has been or is in the process of being approved as intrinsically safe by MSHA and other criteria as the Director determines, a description of the process used in making that determination and a certification in the following form: "I, the undersigned, herby certify that this product, to the best of my knowledge and belief, meets or exceeds all requirements set forth in W. Va. CSR Title 56 Series 4-9", that the product has been tested for functionality in West Virginia underground mines, that the product has been or is in the process of being approved as intrinsically safe by MSHA and other criteria as the Director determines.

9.6. No later than July 31, 2007 all underground mine operators shall submit a communication/tracking plan for approval by the Director in accordance with W. Va. Code Chapter 22A Article 1-36. The design, development, submission, and implementation of the communication/tracking plan shall be the responsibility of the operator of each mine.

9.7. Within thirty (30) calendar days after submission of the communication/tracking plan, the Director shall either approve the communication/tracking plan, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

9.8. Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its plan, a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the communication/tracking system and for installation and ongoing maintenance.

9.9. The operator shall submit certified progress reports no less frequently than every sixty (60) calendar days until full compliance is achieved.

9.10. If the Director, in his sole discretion, determines that an operator has failed to provide an communication/tracking plan or progress report, has provided an inadequate communication/tracking plan or progress report, has failed to comply with its approved communication/tracking plan or compliance schedule, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with W. Va. Code Chapter 22A Article 2-55 or this rule, the Director shall issue a cessation order to the operator for the affected mine under W. Va. Code Chapter 22A Article 1-15.

9.11. In developing the communication/tracking plan and any revisions, the operator shall take into consideration the needs for emergency communications and tracking/locating resulting form accidents as described at W. Va. Code Chapter 22A Article 2-66(a), physical features of the particular mine, emergency plans, existing communication infrastructure, communications required under W. Va. Code Chapter 22A Article 1-35(k)and 2-42 and W. Va. CSR Title 36 Series 2-2 and 5-2, advances in communication/tracking technologies and any other aspect of the particular mine the operator deems relevant to the development of the communication/tracking plan.

9.12. The proposed communication/tracking plan shall describe the structure and operations of the separate or integrated communication/tracking system(s) and its role in emergency response specific to the mine shall be detailed and submitted to the Director and, once approved, to the mine rescue teams providing coverage with an updated mine rescue program pursuant to W. Va. Code Chapter 22A Article 1-35(q). Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above.

9.13. The proposed communication/tracking system shall include the ability for:

9.13.1. A communication center monitored at all times during which one or more miners are underground.

9.13.1.1. This center shall be staffed by miners holding a valid underground miners certificate, and trained and knowledgeable of the installed communications/ tracking systems, monitoring and warning devices, travel ways, and mine layout.

9.13.1.2. Individuals not possessing a valid underground miner's certificate but working full-time as a communication center operator on or before May 25, 2006 shall be allowed to continue as communications center operators at that mine provided they will have successfully completed no later than December 31, 2006 a certified 80 hour underground miners apprentice training program, as defined in W. Va. CSR Title 48 Series 2-2.7(a), renewed annually pursuant to W. Va. CSR Title 48 Series 2-2.8(a) and documentation is available for inspection consistent with W. Va. CSR Title 36 Series 24-5;

9.13.2. Knowing the location of all miners immediately prior to an event by tracking/locating device in the escape-ways, normal work assignments, or notification of the communication center;

9.13.3. Knowing the location of miners in the escape-ways after an event providing the tracking system is still functional;

9.13.4. Check-in and check-out with the communication center by miners prior to entrance and exit from bleeders and remote or seldom used areas of the mine (all times shall be logged);

9.13.5. Allowing two way communications coverage in at least two separate air courses and at least one of which shall be an intake;

9.13.6. Maintaining communication/tracking after loss of outside power and maintain function both inby and outby of the accident event site with suitable supply of equipment for rapid reconnection;

9.13.7. Maintain a surface supply of communication/ tracking devices for use by emergency rescue personnel;

9.13.8. Allow for communication to surface at all required emergency shelters/chambers;

9.13.9. All miners and likely emergency responders shall be trained in the use, limitations and inter-operability of all components of the communication and tracking/locating system. This shall be incorporated into ongoing required training. All training shall be recorded and made available upon request;

9.14. The operator shall provide a schedule of compliance for the communication/tracking plan, which shall include:

9.14.1. A narrative description of how the operator will achieve compliance with above requirements;

9.14.2. A schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

9.14.3. A statement indicating when the implementation of the proposed plan will be complete.

9.15. The operator shall provide as attachments to its communication/tracking plan:

9.15.1. A statement of the analysis and evaluation required in developing its plan;

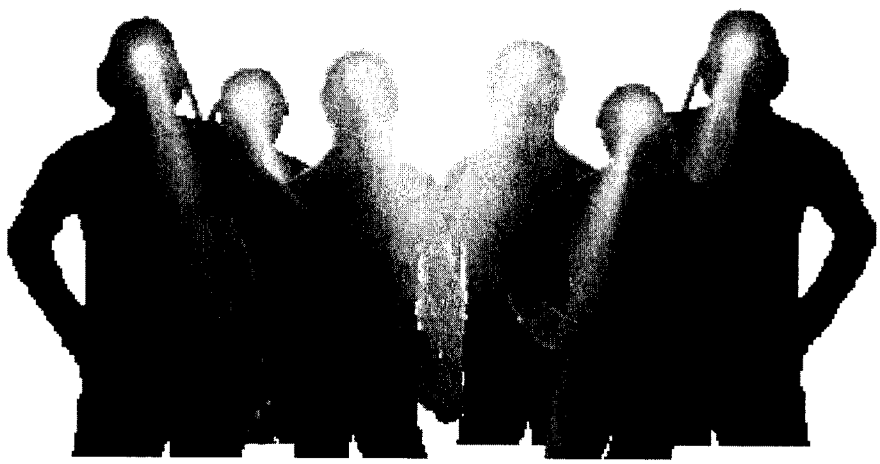
9.15.2. A statement indicating the initial training dates for implementation of the communication/ tracking system and how the communication/tracking system will be incorporated in other required training;

9.15.3. A statement regarding how the communications/tracking system will be tested and maintained; and

9.15.4. The name of the person or persons representing the operator, including his or her title, mailing address, email address and telephone number, who can be contacted by the Director for all matters relating to the communication/tracking plan and weekly testing of the system.

9.16. After the Director has approved an operator's communication/tracking plan, the operator shall submit revisions to the communications plan at any time that changes in operational conditions result in a substantive modification in the communication/tracking system. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the communications/tracking plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

9.17. The Director may require modifications to a communication/tracking plan at any time following the investigation of a fatal accident or serious injury, as defined by W. Va. CSR Title 36 Series 19-3.2, if such modifications are warranted by the findings of the investigation.



Mine Safety Recommendations

Report to the Director of the Office of Miners' Health, Safety and Training

By the
West Virginia
Mine Safety Technology Task Force

As required by West Virginia Code §56-4-4

May 29, 2006

WEST VIRGINIA OFFICE OF MINERS' HEALTH SAFETY TRAINING

ABSTRACT

The Sago and Aracoma disasters and their fourteen deaths, highlighted needed improvements in equipment, capabilities and processes for mine emergency response. The resultant worldwide attention has forever shifted the public's view of underground mine safety.

With the resolve of our government leaders, operators and labor representatives, we have embarked on a mission to improve mine health and safety, thus safeguarding the miners that fuel our nation. The Mine Safety Technology Task Force was charged with the duty of investigating and evaluating options and developing guidelines geared toward protecting the lives of our miners. Special emphasis has been placed on the systems and equipment necessary to sustain those threatened by explosion, fire or other catastrophic events while attempting escape or awaiting rescue.

The West Virginia Mine Safety Technology Task Force Report provides a summary of commercial availability and functional and operational capability of SCSR's, emergency shelters, communications, and tracking along with recommendations regarding implementation, compliance and enforcement. The Mine Safety Technology Task Force was established by an Emergency Rule §56-4-4 and consists of six members with more than 200 years collective underground mining experience. They identified critical issues, then queried vendors and subject matter experts for capabilities, limitations and options regarding self-contained self-rescuers, emergency shelters/chambers, communications/tracking and related safety issues during its studies from March 9th to May 25th 2006. The Task Force concluded in each area examined that enhancements of existing health and safety were to be achieved through more widespread

application of existing technologies. However, in each case we also found significant opportunities for further advancements. The report examines each area in detail and outlines recommendations for amending current West Virginia Miner's Health, Safety and Training rules. The Task Force also advances a challenge to West Virginia to maintain and advance the state's current national leadership role in mine health and safety established through the actions of West Virginia Senate Bill 247 through aggressively pursuing the recommendations included in this report.

Mine Safety Recommendations

of the

Mine Safety Technology Task Force

Presented to James Dean, Director

Office of Miners' Health, Safety and Training

May 29, 2006

In Fulfillment of the Requirements of

Emergency Rules Governing Protective Clothing and Equipment §56-4-4

Dale Birchfield

Theodore Hapney

Terry Hudson

Todd Moore

Gary Trout

Stephen Webber

PREFACE

The Task Force recognizes and appreciates the tremendous amount of hours our Governor spent with the families of the victims at the Sago and Aracoma disasters. This sincerity by the Governor during these onsite visits demonstrates his concern and compassion towards mine health and safety and the effects it has on miners and their families. We applaud the Governor for his swift action in proposing emergency mine safety legislation to enhance mine safety and provide additional protection for miners when events such as this occur.

The Task Force also applauds the Legislature for unanimously passing Senate Bill 247. This swift action by the Governor and the Legislature is indicative of the dedication by our state officials to do whatever is necessary, to provide the best possible protection to the men and women who work in our mines. The Task Force urges the Governor, the Legislature and the Director of the WV Office of Miners Health, Safety and Training to continue that same dedication by implementing these recommendations and providing necessary funding.

The Task Force would like to acknowledge and thank Acting Director, Jim Dean and his staff for their participation and support of the Task Force as we carried out our assignment.

The Task Force would especially like to thank Randall Harris for his assistance in providing technical expertise, making arrangements and scheduling visits of vendors, government and state officials, researching technical issues and assisting our understanding of highly technical issues that was tremendously vital to our work and allowed us to complete our work within the time frame given the Task Force.

Table of Contents

I. EXECUTIVE SUMMARY

The West Virginia Mine Safety Technology Task Force concluded in each of the principal areas upon which it focused: self-contained self-rescuers, emergency shelters/chambers, and communications/tracking that there were significant enhancements in miners health and safety to be achieved through wider application of existing technologies and techniques. However, the Task Force also concluded that there is considerable opportunity for improvements in all areas and in the techniques of integrating technologies and procedures to increase performance and survivability of mine health and safety systems.

This report provides details of the Task Force's findings and resultant recommendations in the areas of SCSR's, emergency shelters/chambers, communication/tracking, and some related areas upon which the group focused. There were many other areas of mine health, safety, and training that are affected by technology that fall within the charge of the Task Force but there was not sufficient time for the group to focus on these prior to the required May 29th date of this report. The Task Force is committed, if called upon, to focus on these areas over the next few months and issue subsequent findings and recommendations.

The Task Force found that technological advances in mine health, safety and training have been stagnant during the last few decades. There were found to be many reasons for this stagnation, but the Task Force believes the primary reason is the relatively small size of the market in relation to the high costs of research and development, and steps required to acquire regulatory certification. In many market segments where market failures inhibit necessary technological advances, government has stimulated the market place by reducing the financial risk through cost-shared R&D mechanisms such as the federal Small Business Innovative Research program. The Task Force believes West Virginia should support efforts to add such cost-shared R&D programs to the Mine Health and Safety Administration (MSHA) and the National Institute of Occupational Safety and Health (NIOSH) budgets. However, the Task Force believes that West Virginia should go further by establishing a similar program that would further our leadership role. Such a program could provide cost-shared R&D funding that could be leveraged with federal funds by West Virginia small business to focus and advance technology solutions to the mine health, safety and training problems that directly impact our state.

The Task Force has concluded that solutions that focus on 'devices' do not provide the best protection for miners, rather, an approach of looking at devices as part of the system in which they function is appropriate. Therefore, recommendations made require a mine specific evaluation that would determine which of the multiple device options best provide the needed protection and how these additions fit into mine operations, emergency response, and what ongoing training is required by all those likely to use them.

The Task Force has a concern that the devices installed to improve safety, such as battery-powered strobes and radios, may in fact increase the risk of a secondary events caused by damage to the devices in the initial explosion. The Task Force recommends that an independent risk analysis be conducted and therefore does not recommended that battery-powered strobes be installed at this time.

West Virginians owe most of what we have today to our miners and the mines in which they work. They have provided and will continue to provide the core of the State's economic base. Advances in technology to reduce their risk at the Federal level have tended to peak and ebb in direct relations to major mine accidents. The Task Force strongly believes that unless the State takes action to ensure a continual focus on advancing mine health and safety technologies, the current Federal focus will also ebb until the next major accident. We owe it to those whose deaths drove the current focus that the recommendations made here trigger not simply 'a device' but rather 'a process' that will continue to bring the latest advances in technologies to mine health, safety and training.

SELF-CONTAINED SELF-RESCUERS

The key to escape in a toxic atmosphere is the SCSR. In a 2001 study, the National Institute for Occupational Safety and Health (NIOSH) reported that out of 214 miners surveyed 38% had been notified to evacuate a mine because of fire or explosion during their career.[1] US Mine Rescue Association data indicate that the depletion of oxygen and production of carbon monoxide and carbon dioxide cause more fatalities than all other causes combined.[2] Access to and proper operation of SCSR's is a matter of life and death to miners.[3]

[1] Conti, RS [2001] "Responders to Underground Fires", NIOSH, Pittsburgh Research Laboratory
[2] US Mine Rescue Association, http://www.usmra.com/disasters_80on.htm
[3] Immediately following an explosion the typical gas composition is; 6% O_2, 10,000ppm CO, and 11% CO_2 the combination of which is fatal - Foster Miller Associates [1983]: "Recommended Guidelines for Oxygen Self-Rescuers, Volume II", USBM Contract J0199188 p79-80

The Task Force has concluded that options exist to meet SB-247 regarding the sufficient supply of self-contained self-rescuers (SCSR's) to ensure the miners can escape in the event of fire or explosion when mine air has become toxic.

SCSR Recommendations

Under Title 56, Series 4, "Amended Emergency Rules Governing Protective Clothing and Equipment" the Director has required SCSR storage cache plans. The Task Force recommends these rules be amended and SCSR storage cache plans revised to reflect the following:

1. Operators shall revise all SCSR plans and submit those to the Director no later than 60 days after these amendments become final.
2. Operators shall place at least one cache at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine and each active construction or rehabilitation site. Distances greater than five hundred (500) feet not to exceed one thousand (1,000) feet, are permitted. However, where miners are provided with personal SCSR's rated for less than sixty (60) minutes, travel to these caches are not to exceed five (5) minutes as determined by the height/travel time chart as specified in Section 5.3.2.
3. Each of these caches (nearest working face in each working section of the mine and each active construction or rehabilitation site) shall hold two (2) SCSR's that will provide at least 60 minutes of oxygen per unit for each miner. When each miner carries an SCSR that is rated for less than 60 minutes, in which case the cache shall hold three (3) SCSR's for

each miner. The total number of SCSR's to be cached will be based on the total number of miners reasonably likely to be in that area.

4. Operators shall ensure that caches described above also contain an escape kit containing a hammer, a tagline, a supply of chemical light sticks, and an escape-way map.

5. Beginning at the storage cache located at the working section or active construction or rehabilitation site and beltlines, pumping and bleeder areas, and continuing to the surface or nearest escape facility leading to the surface, the operator shall station additional storage caches containing a number of additional SCSR's equal to or exceeding one each for the total number of persons reasonably likely to be in that area at calculated intervals that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam and utilizing the travel times as specified in Section 5.3.2.

6. The Task Force recommends that SB-247 be modified by removing references to "certified intrinsically safe battery-powered strobe lights" due to the concern that damaged strobe lights would create a potential ignition hazard if damaged in an explosion. The Task Force recommends that each SCSR cache have a reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" conspicuously posted at each such cache and that reflective direction signs shall be posted leading to each cache. Cache storage containers shall be of such construction as to protect the SCSR's from normal operational damage, be made of a material that is non-combustible, shall be easy to open during an emergency escape, and shall be noted on the escape-way map.

7. Operators shall provide training in the proper use of SCSR's in simulated emergency situations, which may be on the surface, in all required SCSR training. Training should include but not limited to, manufacturer's required daily inspections, donning and starting the SCSR, ways to maximize duration of the unit, changing between SCSR's, communicating without removing the mouth piece, importance and use of goggles, how to know if the device has failed and what to do if it does, and limitations of the SCSR. Until such time as manufacturers offer an operable training SCSR operators are encouraged to save out-of-service units to activate during training as a supplement to currently available training models. All training shall be recorded and made available upon request.

8. Operators and contractors shall report to the Director all SCSR's in service by manufacturer, model, serial number, mine/contractor ID#, service dates, and results of required inspections. This information shall be submitted electronically as defined by the Director, updated quarterly and will include information on any units removed from service along with reasons. The Director shall compile and analyze the results of this information and distribute a report within 30 days by posting the report on the MHS&T web page, www.wvminesafety.org

EMERGENCY SHELTERS/CHAMBERS

The Task Force has concluded that the first and preferred option for miners in an emergency is to escape. However, it has found that options exist to provide the primary function of an Emergency Shelter/Chamber which is designed to potentially sustain life after a major underground event such as an explosion and where escape is cut off. The Task Force has developed recommended minimum requirements for the emergency shelter/chamber and its use.

In developing recommendations the Task Force reviewed summaries of mine accidents that resulted in barricading of miners and developed a scenario. The scenario used is of an accident in which miners within 1,000 feet of the working face have survived a methane explosion. The Task Force's scenario does not include secondary explosions or on-going fires in the immediate area. The miners will have made every attempt to exit and found all escape ways impassable. As a last resort, they have been forced to return to the shelter/chamber to await rescue. We have assumed that miners approaching the emergency shelter/chamber will have consumed most of their SCSR time, be exhausted from escape attempts, with some injured and all under great stress. In this condition, the miners will need to be protected by the shelter/chamber within minutes of reaching it and for a period of at least 48 hours.

Emergency Shelter/Chamber Recommendations

1. The Director shall require, in each underground mine, an emergency shelter/chamber, it shall be located in a crosscut no more than 1,000 feet from the nearest working face and shall be accurately located on mine maps.
2. The Director may approve, as an alternative to a shelter/chamber, an additional surface opening located no more than 1,000 feet from the nearest working face and accurately located on mine maps.

3. The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support needed to evaluate the performance of emergency shelter/chamber components/systems, and to review the effectiveness of emergency shelter/chamber plans.
4. The Director shall, no later than July 10, 2006, issue an open opportunity for emergency shelter/chamber providers to submit products for approval.
5. The applicant is to submit documentation including a certification by an independent licensed professional engineer that its unit meets the requirements.
6. The Director shall maintain a current list of approved emergency shelter/chambers on the West Virginia MHS&T web site www.wvminesafety.org
7. After an emergency shelter/chamber has been approved, any modifications must be submitted for approval by the Director.
8. The Director shall convene the Mine Safety Technology Task Force not less than once per month through June 30, 2007 for the purpose of reviewing progress by manufacturers, regulators, and operators toward achieving the goals set forth in SB-247 and to review the functional and operational capability of necessary mine safety and health technologies. The Task Force shall submit a report to the Director of its findings and recommendations.
9. No later than April 15, 2007 all underground mine operators shall submit an emergency shelter/chamber plan for approval by the Director. The design, development, submission, and implementation of the shelter/chamber plan shall be the responsibility of the operator of each mine.

10. Within thirty (30) calendar days after submission of the emergency shelter/chamber plan, the Director shall either approve the emergency shelter/chamber plan or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

11. Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its emergency shelter/chamber plan a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the emergency shelter/chamber and for installation and ongoing maintenance.

12. After the Director has approved an operator's emergency shelter/chamber plan, the operator shall submit revisions to the emergency shelter/chamber plan at any time that changes in operational conditions result in a substantive modification. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the emergency shelter/chamber plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

13. If the Director, in his sole discretion, determines that an operator has failed to provide an emergency shelter/chamber plan, has provided an inadequate emergency shelter/chamber plan, has failed to comply with its approved emergency shelter/chamber plan, or has failed

to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

14. In developing the emergency shelter/chamber plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, advances in emergency shelter/chamber technologies and any other aspect of the particular mine the operator deems relevant to the development of the emergency shelter/chamber plan.

15. A copy of the approved emergency shelter/chamber plan shall be provided to the mine rescue teams providing coverage for the mine. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above parties.

16. The proposed emergency shelter/chamber plan shall:
    - describe the structure and operations of the emergency shelter/chamber and its role in emergency response;
    - ensure that emergency shelters/chambers are included in initial mine hazard training in such a manner that it is in compliance with all manufacturer's requirements and is provided yearly in addition to annual refresher training. All training shall be recorded and made available upon request;

- ensure weekly inspections of emergency shelters/chambers and contents shall be conducted by a certified mine foreman/fireboss and recorded in weekly ventilation examination book;
- ensure that weekly safety meetings review the current location of applicable emergency shelters/chambers and results of the latest inspection;
- ensure that emergency shelters/chambers shall be equipped with easily removable tamper-proof tags such that a visual indication of unauthorized access to the emergency shelter/chamber can be detected; and
- ensure that the mine's communication center shall monitor any communication systems associated with the emergency shelter/chamber at all times that the mine is occupied.

17. The proposed emergency shelter/chamber shall include the ability to:
    - provide a minimum of 48 hours life support (air, water, emergency medical supplies, and food) for the maximum number of miners reasonably expected on the working section;
    - be capable of surviving an initial event with a peak overpressure of 15 psi and a flash temperature of 300 degrees Fahrenheit;
    - be constructed such that it will be protected under normal handling and pre-event mine conditions;
    - provide for rapidly establishing an internal shelter atmosphere of
      O_2 above 19.5%,

CO_2 below 0.5%,

CO below 50 ppm, and

an 'apparent-temperature' of 95 degrees Fahrenheit;

- provide the ability to monitor carbon monoxide and oxygen inside and outside the shelter/chamber;
- provide a means for entry and exit that maintains the integrity of the internal atmosphere;
- provide a means for intrinsically safe power if required;
- provide a minimum eight quarts of water per miner;
- provide a minimum of 4000 calories of food per miner;
- provide a means for disposal of human waste to the outside of the shelter/chamber;
- provide a first aid or EMT kit in addition to a section first aid kit;
- have provisions for inspection of the shelter/chamber and contents;
- contain manufacturer recommended repair materials;
- provide a battery-powered internal strobe light visible from the outside indicating occupancy;
- provide a means of communications to the surface; and
- only contain MSHA approved materials where applicable.

18. The Director may require modifications to an emergency shelter/chamber approval or an emergency shelter/chamber plan at any time following the investigation of a fatal accident

or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.

COMMUNICATIONS/TRACKING

In completing its charge to evaluate availability, functional and operational capacity of required communication and tracking devices, the Task Force reviewed multiple products, designs, and approaches and has determined that while no single product exists to meet all the requirements, the intent of SB-247 can be met in most if not all mines by employing separate systems, possibly requiring one for communications and one for tracking.

Further, the Task Force has determined that through utilizing multiple products and procedures an integrated communication/tracking system can be installed that would meet the intent of the law … "to protect miners in an emergency".

Communications/Tracking Recommendations

1. The Director shall require, in each underground mine, an integrated communication/ tracking system, a component of which shall be a communication center monitored at all times during which one or more miners are underground.
2. The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support to evaluate the performance of individual communication/tracking systems and review the effectiveness of communication/tracking plans.
3. The Director shall convene the Mine Safety Technology Task Force not less than once per month through June 30, 2007 for the purpose of reviewing progress by manufacturers, regulators, and operators toward achieving the goals set forth in SB-247 and other mine

health and safety technology to promote the availability, functional and operational capability of necessary mine safety and health technologies. The Task Force shall submit a report to the Director of its finding and recommendations.

4. No later than August 31, 2007 all underground mine operators shall submit a communication/tracking plan for approval by the Director. The design, development, submission, and implementation of the communication/tracking plan shall be the responsibility of the operator of each mine.

5. Within thirty (30) calendar days after submission of the communication/tracking plan, the Director shall either approve the communication/tracking plan, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

6. Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its plan, a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the communication/tracking system and for installation and ongoing maintenance.

7. After the Director has approved an operator's communication/tracking plan, the operator shall submit revisions to the communications plan at any time that changes in operational conditions result in a substantive modification in the communication/tracking system. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days

after receipt by the Director of any proposed revisions or modifications to the communications/tracking plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

8. If the Director, in his sole discretion, determines that an operator has failed to provide a communications/tracking plan, has provided an inadequate communications/tracking plan, has failed to comply with its approved communications/tracking plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

9. In developing the communication/tracking plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, existing communication infrastructure, advances in communication/tracking technologies and any other aspect of the particular mine the operator deems relevant to the development of the communication/tracking plan.

10. The proposed communication/tracking plan shall describe the structure and operations of the separate or integrated communication/tracking system(s) and its role in emergency response specific to the mine shall be detailed and submitted to the Director and, once approved, to the mine rescue teams providing coverage for the mine. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above.

11. The proposed communication/tracking system shall include the ability for:

- a communication center monitored at all times during which one or more miners are underground. This center shall be staffed by persons holding a valid underground miners certificate, and trained and knowledgeable of the installed communications/ tracking systems, monitoring and warning devices, travel ways, and mine layout. Individuals not possessing a valid underground miner's certificate but working full-time as a communication center operator on or before May 25, 2006 shall be allowed to continue as communications center operators at that mine provided they will have successfully completed no later than December 31, 2006 a certified 80 hour underground miners apprentice training program and documentation is available for inspection;
- knowing the location of all miners immediately prior to an event by tracking/locating in the escape-ways, normal work assignments, or notification of the communication center;
- knowing the location of miners in the escape-ways after an event providing the tracking system is still functional;
- check-in and check-out with the communication center by persons prior to entrance and exit from bleeders and remote or seldom used areas of the mine (all times shall be logged);
- allowing two way communications coverage in at least two separate air courses and at least one of which shall be an intake;

- maintaining communication/tracking after loss of outside power and maintain function both inby and outby of the event site with suitable supply of equipment for rapid reconnection;
- maintain a surface supply of communication/ tracking devices for use by emergency rescue personnel;
- allow for communication to surface at all required shelters/chambers;
- all miners and likely emergency responders shall be trained in the use, limitations and inter-operability of all components of the communication and tracking/locating system. This shall be incorporated into required training. All training shall be recorded and made available upon request;

12. The operator shall provide a schedule of compliance for the communication/tracking plan, which shall include:
    - a narrative description of how the operator will achieve compliance with above requirements;
    - a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and
    - a statement indicating when the implementation of the proposed plan will be complete.
13. The operator shall provide as attachments to its communication/tracking plan:
    - a statement of the analysis and evaluation required in developing its plan;

- a statement indicating the initial training dates for implementation of the communication/ tracking system and how the communication/tracking system will be incorporated in other required training;
- a statement regarding how the communications/tracking system will be tested and maintained; and
- the name of the person or persons representing the operator, including his or her title, mailing address, email address and telephone number, who can be contacted by the Director for all matters relating to the communication/tracking plan and weekly testing of the system.

14. The Director may require modifications to a communication/tracking plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.

RELATED SAFETY ISSUES

The Task Force found many related safety and health issues important to miners but was unable to dedicate significant time to any. It provides the following recommendations and will work with the Director and the Board of Coal Mine Health and Safety to better explore these related issues.

LIFELINES

In lieu of installed lifelines in track or belt entries, markers such as floor mats with arrows, fish plate reflectors, red/green lasers shall be installed at distances not to exceed 1,000 feet or line of sight, or other equivalent devices may be used if approved by the Director.

SEALS

'Omega" type blocks shall not be used in future seal construction. They may, however, be used for other type ventilation controls. The Task Force applauds the Director's May 12, 2006 action imposing a moratorium on "Omega" type block installations and MHS&T's ongoing review of all existing installations. It is recommended that immediate corrective action be taken where warranted.

SEISMIC LOCATING DEVICES

The Director shall provide portable seismic locating systems at each regional office for use in locating trapped miners. Each office will maintain a trained staff that shall upon notification from Homeland Security Office, be capable of delivering the system to the mine site and to deploy the system immediately and without delay. These persons shall practice with the said systems at least annually at different mine sites.

MINE RESCUE TEAMS

The Task Force supports and applauds the actions taken by the Board of Coal Mine Health and Safety and the Director of the Office of MHS&T for their efforts to address mine rescue capabilities and other mine rescue concerns in the State of West Virginia. The Task Force recommends these efforts be expanded to reflect currently available technology for mine rescue and fire fighting.

RECOMMENDED IMPLEMENTATION TIMELINE

Year	Month	SCSR	Shelters	Comm/Track
2006	June	Amended rules issued based upon recommendations		
	July	Proposed Final Rules submitted to Legislature Submit Revised SCSR Plan		
	August	Director Approves/Rejects Revised SCSR Plans	July 1 - MHS&T Acquire Technical Support July 10 – MHS&T Issue Opportunity for approvals	
	September		Vendors working with operators, MSHA, and MHS&T to test, refine and get approvals	
	October		Task Force monitors and issues monthly reports	
	November		MHS&T announces approvals as done	
	December		Operators and vendors develop and test proposed plans	
2007	January			
	February			
	March			
	April		April 15 - Submit Shelter/Chamber Plan	
	May		Director Approves/Rejects Submit PO's with approval	
	June			
	July			July 31 – Submit Comm/Trac Plan
	August			Director Approves/Rejects Submit PO's with approval

Installation will progress according to schedules included in approved plans.

II. SELF-CONTAINED SELF-RESCUERS

SUMMARY

The Task Force has concluded that options exist to meet SB-247 regarding the sufficient supply of self-contained self-rescuers (SCSR's) to ensure the miners can escape in the event of fire or explosion and mine air has become toxic.

In developing recommendations the Task Force reviewed summaries of mine evacuations, operation of SCSR's, capabilities and limitations of SCSR's, metabolic parameters of miners during escapes, cache storage options, and aids to escape.

The Task Force concluded that caches should be provided near the most likely locations of miners at the time of an event and every 30 minutes of travel time through designated escape ways to the nearest surface opening or shaft. The Task Force also concluded that SCSR's certified by MSHA/NIOSH for at least 60 minutes shall be cached at quantities outlined in a plan approved by the Director.

The Task Force concluded that SCSR caches should be protected from normal mining operational hazards, be constructed of a non-combustible material, will be easy to locate during an emergency, be noted on escape-way maps, and easy to open. We also find that strategic caches should contain basic aids for escape.

The Task Force recommends that SCSR training be increased with the inclusion of realistic simulations.

The Task Force recommends that a statewide SCSR reliability tracking system be initiated to enhance the understanding of SCSR performance and to allow recall of units if required.

BACKGROUND

The key to escape in a toxic atmosphere is the SCSR. In a 2001 study the National Institute for Occupational Safety and Health (NIOSH) reported that out of 214 miners surveyed 38% had been notified to evacuate a mine because of fire or explosion during their careers.[4] US Mine Rescue Association data indicate that the depletion of oxygen and production of carbon monoxide and carbon dioxide cause more fatalities than all other causes combined.[5] Access to and proper operation of SCSR's is a matter of life and death to miners.[6]

The Task Force SCSR recommendations address:

- Mine-wide emergency strategies that take into account the capabilities and limitations of the SCSR's
- Impacts of traveling long distances in adverse conditions, high heat and humidity
- Realistic training
- Aids to escape

[4] Conti, RS [2001] "Responders to Underground Fires", NIOSH, Pittsburgh Research Laboratory
[5] US Mine Rescue Association, http://www.usmra.com/disasters_80on.htm
[6] Immediately following an explosion the typical gas composition is; 6% O_2, 10,000ppm CO, and 11% CO_2 the combination of which is fatal - Foster Miller Associates [1983]: "Recommended Guidelines for Oxygen Self-Rescuers, Volume II", USBM Contract J0199188 p79-80

In addressing SCSR's the Task Force reviewed published studies on mine fires and explosions with special attention to the behavior of miners while using SCSR's.[7] The Task Force determined that due to reports of miners having difficulty using or being recovered with unused SCSR's that it needed a better understanding of the capabilities and limitation of the devices and most likely requirements of the escaping miner.[8]

The Task Force began with researching how the various devices work. It found there are presently two basic SCSR designs. One provides oxygen from compressed gas and the other through a chemical reaction. Both designs utilize a means of removing exhaled carbon dioxide and protect from inhaling carbon monoxide and smoke. All units provide a mouth piece that fits behind the lips and is clasped with the teeth along with a clip that restricts air through the nostrils and a bag to hold reserves of oxygen-rich air. The carbon dioxide is removed through a chemical reaction; the ability to remove sufficient carbon dioxide is a critical factor determining the unit's physical size and duration.

Currently there are only three manufacturers of MSHA/NIOSH certified SCSR's.[9] Two produce oxygen using chemicals and one provides compressed oxygen. The certification process involves a manufacturer's unit being tested by a human subject in a defined series of exercises with the goal being to maintain the subject's metabolic indicators within specified ranges. The units are rated on the time segments of these exercises it successfully passed i.e., 10, 30, or 60

[7] Vaught C, et al [2000]: "Behavioral and Organizational Dimensions of Underground Mine Fires", NIOSH also Kavitz, J [1977]: "An Examination of Major Mine Disasters", NIOSH also DeRosa, MI [2004]: "An Analysis of Mine Fires 1990-1999", NIOSH IC9470 also US Mine Rescue Association [2006]: "Mine Accidents 1980-2006", http://www.usmra.com/disasters_80on.htm
[8] Mine accident reports can be found on the MSHA web site at http://www.msha.gov/fatals/fab.htm
[9] Interview with John Kovac, NIOSH Pittsburgh Research Laboratory

minutes. There is no attempt to test beyond the manufacturer's requested duration target. As a result MSHA/NIOSH cannot endorse manufacturer claims that their units will go beyond the rated durations or time a unit will provide breathable air under exertion rates other than those of the MSHA/NIOSH test.[10]

MSHA/NIOSH also conducts periodic evaluations of selected SCSR's removed from active mines. These evaluations are conducted using a testing machine verses human subjects and are designed to identify potential problems, **not as a quality control of certified performance.** These tests have identified some problems in design, materials, and maintenance over the years which manufacturers have corrected. MSHA/NIOSH also accepts volunteered information on failed units along with descriptions of the causes of failure and uses this information to work with manufacturers on improvements.[11]

Several studies were reviewed by the Task Force that looked at performance in simulated underground mine escapes. These studies provided the Task Force with insights into the metabolic requirements of an escaping miner. Since every mine is different and every miner unique, it is not surprising that there are deviations from the certified durations of SCSR's when tested in the real-world verses the laboratory.[12] MSHA/NIOSH claims that miners' lack of familiarity with using SCSR's in the stress of an escape situation accounts for some of the

[10] Interview with John Kovac, NIOSH Pittsburgh Research Laboratory
[11] Kyriazi N and Shubilla JP [2002]: "Self-Contained Self-Rescuer Field Evaluation: Seventh-Phase Results", RI9656 - also see RI9401, RI9635, and RI9451
[12] Foster Miller Associates [1983]: "Recommended Guidelines for Oxygen Self-Rescuers, Volume II, Escape Time Studies", USBM Contract J0199118

variance. While this explains most of the findings, it adds to the task of determining adequate spacing for SCSR storage caches.

After consulting with manufacturers and experts from MSHA/NIOSH and drawing upon its own experience, the Task Force concluded that a safety margin regarding the typical distance traveled needed to be applied by discounting existing SCSR's model's certified duration by 50%. This was derived by looking at escape simulations studies from the US Bureau of Mines[13], United Kingdom[14], and South Africa[15]. Collectively these studies found that actual useful life varied from 26% to 125% of the MSHA/NIOSH certified durations. The Task Force also took into consideration reports indicating miner difficulties in donning the SCSR's in real and simulated emergencies[16], and the findings of the MSHA/NIOSH field evaluations[17]. The recommended approach provides a 100% safety margin against the unexpected in both travel time and SCSR operation.

The Task Force is troubled that there has been little change in the underlying technology and the design of these units in the last 30 years. The original SCSR design criteria were defined by the National Academy of Engineering in a 1970 study[18].

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[13] Foster Miller Associates [1983]: "Recommended Guidelines for Oxygen Self-Rescuers, Volume II, Escape Time Studies", USBM Contract J0199118

[14] Jones, BJ et al [2003]: "Use of self-rescuers in hot and humid mines", Research Report #180

[15] Schreiber, WL [2004]: "Annual Report on SCSR Monitoring in the South African mining industry for the period January – December 2003", Department of Minerals and Energy, # 2004-0153

[16] Vaught C, et al [2000]: "Behavioral and Organizational Dimensions of Underground Mine Fires", NIOSH

[17] Kyriazi N and Shubilla JP [2002]: "Self-Contained Self-Rescuer Field Evaluation: Seventh-Phase Results", RI9656 - also see RI9401, RI9635, and RI9451 – also presentation by John Kovac, NIOSH to the Colorado School of Mines in April 2003, "Analysis of SCSR Problems"

[18] National Academy of Engineering [1970]: "Mine Rescue and Survival", Washington DC

Recent workshops sponsored by MSHA and NIOSH to explore SCSR options are encouraging; however, the identified potential changes appear to be only in design rather than in the underlying technology.[19] Indicative of the stagnation in the mine health and safety technology market place, many of the design changes at the workshop were rediscoveries of those proposed in the late 1970's by the US Bureau of Mines but never brought through certification by manufacturers.[20]

After discussions with MSHA, NIOSH, and current and potential manufacturers, the Task Force believes this situation is due to the limited size of the mine safety market (estimated 80,000 units are deployed in the US[21]) and relatively slow turnover of this installed base (about 15% per year[22]). These facts, taken with the relatively low gross margin to the manufacturers[23], relatively high costs of R&D and a lengthy certification process,[24] act as barriers for innovation in SCSR technologies. Based upon the Task Force's review, at a minimum, there is a need for innovation in indicators for SCSR condition before and during use, longer duration smaller sized SCSR's, improved CO_2 scrubbers, lowered breathing resistance, realistic training systems, and easier inventorying means such as RFID tags or bar codes. The Task Force recommends that the state not only support efforts in Congress to increase development funding for NIOSH but also

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[19] Kovac J [2006] "Self-Contained Self-Rescuer (SCSR) Technology: Capabilities/Challenges", NIOSH presentation at Beckley Mine Academy March 30, 2006

[20] Chironis, NP [1977] "Operating Handbook of Underground Mining", Coal Age Mining Informational Services ISBN: 0070114579

[21] Discussions with NIOSH and manufacturers allowed for a rough estimate by the Task Force that was affirmatively vetted with these same groups

[22] Based on confidential discussions with manufacturers regarding their expected production levels for 2006 prior to changes in the law and the estimate of in service SCSR's

[23] Confidential interviews with manufacturers

[24] Perception of the manufacturers – NIOSH believes the process is efficient

initiate a program of its own to focus on issues specific to West Virginia mine health and safety problems and encourage local small businesses to bring innovations forward.

MSHA/NIOSH acknowledges a need to better understand the status of SCSR's actually in the possession of miners. MSHA/NIOSH have worked with manufacturers to develop workable testing and mines are supplied the equipment from their vendors. However, there is no standard means of determining if these mine-level testing programs ensure the viability of the SCSR's in the mine. Also beneficial would be a statistically based means of identifying problems of in-service units by determining reasons for destruction or out-of-service events. This data would provide critical information on the performance of deployed SCSR's, early warning of problems, and the ability to recall specific units for service if required. The Task Force agrees and recommends that West Virginia initiate such a program.

The Task Force believes that training is a critical issue for miners in all areas, but particularly regarding SCSR's. Most miners go through their entire careers and never have the experience of donning an SCSR. When a miner finds the first time he actually uses an SCSR is in the midst of an emergency, he needs to be confident he can do everything right the first time. The Task Force believes the best way to accomplish this is through realistic SCSR simulation during training. Many of the reports of SCSR failure investigated by MSHA/NIOSH concluded that the miners had misinterpreted typical SCSR operation as a malfunction.[25] Breathing oxygen, from a cylinder or from a chemical in a can, while in a smoke-filled mine is not the same as using a non-working training unit in a classroom. Training shall include manufacturers'

[25] Vaught, CJ et al [1999]: "Worker Responses to Realistic Evaluation Training", NIOSH Pittsburgh Research Laboratory

required daily inspection of each unit, donning and starting the SCSR, ways to maximize duration of the unit, changing between SCSR's, communicating without removing the mouth piece, importance and use of goggles, how to know if the device has failed and what to do if it does, and limitations of the SCSR. All training shall be recorded and made available upon request. While no manufacturer currently offers such a training device, the Task Force strongly encourages the development and incorporation into training of a simulation device that would allow miners to experience the realistic or simulated sensations of breathing through an active unit. Until such time, operators are encouraged to save out-of-service units to be activated during training as a supplement to currently available training models.

When smoke is encountered underground, visibility is reduced, anxiety levels increase and decision-making skills become clouded[26]. To aid in a smoke-filled escape, the Task Force recommends that caches at the working section, active construction or rehabilitation sites contain a tagline to allow members of groups escaping to stay together in zero visibility by each holding the line, a supply of chemical light sticks that can be started and dropped periodically as they escape to warn the miners if they have accidentally doubled back, a hammer to bang on roof bolts and an escape-way map.

DEFINITIONS

Self-Contained Self-Rescuer (SCSR) means a type of closed circuit self-contained breathing apparatus approved by MSHA and NIOSH under 42 CFR part 84 for escape only in underground mines. SCSR's are not to be confused with Filter Self-Rescuer (FSR) that does not

[26] Vaught, CJ et al [1995]: "Decision Making During a Simulated Mine Fire Escape", NIOSH

supply or generate oxygen. The Task Force recommends that FSR's not be allowed in West Virginia mines.

SCSR Storage Cache means a non-combustible container constructed to withstand normal mine conditions and protect a number of SCSR's. The cache shall allow easy access for inspection of the SCSR's and easy access for miners who are escaping.

REQUIREMENTS

Operators shall place at least one cache at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine and each active construction or rehabilitation site. Distances greater than five hundred (500) feet, not to exceed one thousand (1,000) feet, are permitted. However, where miners are provided with personal SCSR's rated for less than sixty (60) minutes, travel to these caches are not to exceed five (5) minutes as determined by the height/travel time chart specified in Section 5.3.2.

Each of these caches (nearest working face in each working section of the mine and each active construction or rehabilitation site) shall hold two (2) SCSR's that will provide at least 60 minutes of oxygen per unit for each miner. When each miner carries an SCSR that is rated for less than 60 minutes, in which case the cache shall hold three (3) SCSR's for each miner. The total number of SCSR's to be cached will be based on the total number of miners reasonably likely to be in that area.

Operators shall ensure that caches described above also contain an escape kit containing a hammer, a tagline, a supply of chemical light sticks, and an escape-way map.

Beginning at the storage cache located at the working section or active construction or rehabilitation site and beltlines, pumping and bleeder areas, and continuing to the surface or nearest escape facility leading to the surface, the operator shall station additional storage caches containing a number of additional SCSR's equal to or exceeding one each for the total number of persons reasonably likely to be in that area at calculated intervals so that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam and utilizing the travel times specified in Section 5.3.2.

The Task Force recommends that SB-247 be modified by removing references to "certified intrinsically safe battery-powered strobe lights" due to the concern that damaged strobe lights would create a potential ignition hazard if damaged in an explosion. The Task Force recommends that each SCSR cache have a reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" conspicuously posted at each such cache and that reflective directional signs shall be posted leading to each cache. Cache storage containers shall be of such construction as to protect the SCSR's from normal operational damage, be made of a material that is non-combustible, shall be easy to open during an emergency escape, and shall be noted on the escape-way map.

Operators shall provide training in the proper use of SCSR's in simulated emergency situations, which may be on the surface, in all required SCSR training. Training shall include, but not be limited to, manufacturer's required daily inspection of unit, donning and starting the SCSR, ways to maximize duration of the unit, changing between SCSR's, communicating without removing the mouth piece, importance and use of goggles, how to know if the device has failed and what to do if it does, and limitations of the SCSR. Until such time as manufacturers offer an operable training SCSR, operators are encouraged to save out-of-service units to activate during training as a supplement to currently available training models. All training shall be recorded and made available upon request.

Operators and contractors shall report to the Director all SCSR's in service by manufacturer, model, serial number, mine/contractor ID#, service dates, and results of required inspections. This information shall be submitted electronically as defined by the Director, updated quarterly and will include information on any units removed from service along with reasons. The Director shall compile and analyze the results of this information and distribute the report within 30 days by posting a report on the MHS&T web page.

COMMERCIAL AVAILABILITY

The Task Force reviewed SCSR's from CSE, Drager and Ocenco. All units are MSHA/NIOSH approved and commercially available although manufacturers report shipping delays exceeding 6 months due to manufacturing capability limitations.

OPTIONS REVIEWED

Chemical generated oxygen

Units that generate oxygen in the SCSR are based upon a chemical reaction of water vapor for exhaled breath and a potassium oxide. The reaction releases oxygen as byproduct while capturing a small amount of carbon dioxide. The carbon dioxide is captured in a separate chemical reaction that converts it into a solid. The amount of oxygen the units can generate and carbon dioxide they can capture is a function of the volume of chemicals. Exhaled air is 'scrubbed' of carbon dioxide and mixed with oxygen in a breathing bag from which miners take breaths. Oxygen levels vary with the breathing rate of the miner, i.e. amount of water vapor they exhale. There is a delay in oxygen production rates as demand increases and decreases with exertion rate.

Cylinder stored oxygen

Units that use oxygen in cylinders also use a chemical for carbon dioxide removal. The amount of oxygen the units can supply is a function of the pressure rating for the cylinder. Exhaled air is 'scrubbed' of carbon dioxide and mixed with oxygen in a breathing bag from which miners take breaths. Oxygen levels can be adjusted through a regulator on the unit.

IMPLEMENTATION, COMPLIANCE AND ENFORCEMENT

Under Title 56, Series 4, "Amended Emergency Rules Governing Protective Clothing and Equipment" the Director has required SCSR storage cache plans. The Task Force recommends these rules be amended and SCSR storage cache plans revised to reflect the following:

1. Operators shall revise all SCSR plans and submit those to the Director no later than 60 days after these amendments become final.
2. Operators shall place at least one cache at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine and each active construction or rehabilitation site. Distances greater than five hundred (500) feet not to exceed one thousand (1,000) feet, are permitted. However, where miners are provided with personal SCSR's rated for less than sixty (60) minutes, travel to these

caches is not to exceed five (5) minutes as determined by the height/travel time chart specified in Section 5.3.2.

3. Each of these caches (nearest working face in each working section of the mine and each active construction or rehabilitation site) shall hold two (2) SCSR's that will provide at least 60 minutes of oxygen per unit for each miner. When each miner carries an SCSR that is rated for less than 60 minutes, in which case the cache shall hold three (3) SCSR's for each miner. The total number of SCSR's to be cached will be based on the total number of miners reasonably likely to be in that area.
4. Operators shall ensure that caches described above also contain an escape kit containing a hammer, a tagline, a supply of chemical light sticks, and an escape-way map.
5. Beginning at the storage cache located at the working section or active construction or rehabilitation site and beltlines, pumping and bleeder areas, and continuing to the surface or nearest escape facility leading to the surface, the operator shall station additional storage caches containing a number of additional SCSR's equal to or exceeding one each for the total number of persons reasonably likely to be in that area at calculated intervals that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam and utilizing the travel times as specified in Section 5.3.2.
6. The Task Force recommends that SB-247 be modified by removing references to "certified intrinsically safe battery-powered strobe lights" due to the concern that damaged strobe lights would create a potential ignition hazard if damaged in an

explosion. The Task Force recommends that each SCSR cache shall have a reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" conspicuously posted at each such cache and that reflective directional signs be posted leading to each cache. Cache storage containers shall be of such construction as to protect the SCSR's from normal operational damage, be made of a material that is non-combustible, shall be easy to open during an emergency escape, and shall be noted on the escape-way map.

7. Operators shall provide training in the proper use of SCSR's in simulated emergency situations, which may be on the surface, in all required SCSR training. Training should include but not be limited to, manufacturer's required daily inspections, donning and starting the SCSR, ways to maximize duration of the unit, changing between SCSR's, communicating without removing the mouth piece, importance and use of goggles, how to know if the device has failed and what to do if it does, and limitations of the SCSR. Until such time as manufacturers offer an operable training SCSR, operators are encouraged to save out-of-service units to activate during training as a supplement to currently available training models. All training shall be recorded and made available upon request.
8. Operators and contractors shall report to the Director all SCSR's in service by manufacturer, model, serial number, mine/contractor ID#, service dates, and results of required inspections. This information shall be submitted electronically as defined by the Director, updated quarterly and will include information on any units removed from service along with reasons. The Director shall compile and analyze the results of this

information and distribute a report within 30 days by posting the report on the MHS&T web page.

III. EMERGENCY SHELTERS/CHAMBERS

SUMMARY

The Task Force has concluded that the first and preferred option for miners in an emergency is to escape. However, it has found that options exist to provide the primary function of an Emergency Shelter/Chamber which is designed to potentially sustain life after a major underground event such as an explosion and where escape is cut off. The Task Force has developed recommended minimum requirements for the emergency shelter/chamber and its use.

In developing recommendations, the Task Force reviewed summaries of mine accidents that resulted in barricading of miners and developed a scenario. The scenario used is of an accident in which miners within 1,000 feet of the working face have survived a methane explosion. The Task Force's scenario does not included secondary explosions or on-going fires in the immediate area. The miners will have made every attempt to exit and found all escape ways impassable. As a last resort, they have been forced to return to the shelter/chamber to await rescue. We have assumed that miners approaching the emergency shelter/chamber will have consumed most of their SCSR time, be exhausted from escape attempts, with some injured miners and all under great stress. In this condition, the miners will need to be protected by the shelter/chamber within minutes of reaching it and for a period of at least 48 hours.

The Task Force has determined that there are commercially available manufactured emergency shelters/chambers that meet and/or exceed the minimum requirements necessary to provide a "last resort" atmosphere when escape is cut-off. It is also evident that there will be

evolution of the designs and that continued support of these innovations by the State and industry will benefit mine safety.

The Task Force concluded that an emergency shelter/chamber or equivalent protection, in the form of additional surface openings, shall be located within 1,000 feet of the nearest working face.

The Task Force reviewed several documents produced during the 1970's and 1980's by the US Bureau of Mines regarding the use of built-in-place shelters using areas, i.e. crosscuts in a mine.

Some Task Force members wanted to prohibit the use of built-in-place shelter in the State of West Virginia, while other Task Force members wanted to allow the use of built-in-place shelters as an option to provide equivalent protection to a shelter/chamber. The Task Force discussed this issue many times throughout our deliberations and could not reach a consenus.

BACKGROUND

An explosion is such a complex phenomenon that no one can explain all of the reasons for its path, fluctuating violence, changing shape, and other characteristics. History proves that most miners survive the initial explosion and flames, however, too many fall victims to toxic air[27].

After a mine explosion, the desire of all miners is to immediately escape. While the provisions of SB-247 enhance their ability to escape, experience has demonstrated that in some instances, a small number of miners may have no alternative but to barricade. Providing a ready

[27] McCoy JF et al [1983]: "Development of Guidelines for Rescue Chambers, Volume II, Appendices", USBM Contract J0387210, page 13

'barricade' equivalent, in the form of an emergency shelter/chamber, should enhance their chances for survival. The record clearly demonstrates that regardless of the quality of the barricade, the lives of miners who have been forced to barricade depend on well-trained mine rescue teams and mine rescue operations[28].

For that reason, the Task Force supports the comprehensive review of West Virginia's mine rescue infrastructure and rules with the intent of enhancing rescue capability.

Since there are no nationally recognized performance standards for emergency shelters/chambers the Task Force spent considerable time determining what minimum standards should apply. It is the Task Force's intent that these recommendations serve truly as minimum standards and that manufacturers strive to exceed these thresholds.

The first step taken was to develop a scenario. In doing this the Task Force looked at studies of mine explosions and fires where barricading was utilized[29]. This was done through review of the professional experience of Task Force members, interviews with mine safety vendors, review of the recent accidents in West Virginia, and documents from MSHA, NIOSH, and other countries.

The Task Force concluded that the function of an emergency shelter/chamber must be ensuring a safe atmosphere for survivors. Documents reviewed indicated that carbon dioxide and carbon monoxide poisoning was by far the cause of most fatalities among those that survived the initial explosion. As methane and liberated coal dust are combusted they first create carbon

[28] McCoy JF et al [1983]: "Development of Guidelines for Rescue Chambers, Volume II, Appendices", USBM Contract J0387210
[29] McCoy JF et al [1983]: "Development of Guidelines for Rescue Chambers, Volume II, Appendices", USBM Contract J0387210

dioxide, then as the oxygen decreases, carbon monoxide. Carbon dioxide increases the breathing rate which pulls more air into the lungs and the air increasingly becomes concentrated with carbon monoxide, this compound binds to the hemoglobin in the blood blocking oxygen. The reduction in oxygen carrying capacity of the blood results in acute hypoxia (oxygen starvation)[30] which results in unconsciousness and eventual death if the concentration exceed 15% for high-risk miners[31].

The next performance criterion the Task Force set was duration. The times from event to either rescue or estimated time of death in mine accidents that resulted in barricading were reviewed. From 1940 to 1980 US Bureau of Mines reported that 127 miners survived behind barricades while 40 died[32]. Each accident was unique and the reporting was not consistent making it difficult to draw statistical conclusions. However, of those that discussed duration the maximum was 54 hours at the Belva No. 1 mine in 1954 and the least was 4 hours at the Pocahontas 31 mine in 1957. The majority were in the 20-30 hour range[33]. Based on its findings, the Task Force set a minimum duration of 48 hours.

The next criterion deals with the physical environment in which the emergency shelter/chamber must survive in order to be useful to those who can not immediately escape. Looking again at reports and drawing upon its own experience, the Task Force found few cases

[30] http://en.wikipedia.org/wiki/Carbon_monoxide_poisoning
[31] Peterson, JE [1975]: "predicting carbonhemoglobin levels resulting from carbon monoxide exposure", J. Appl. Physiol., 39, 633-638 and Davidson, T [2002], Gale Encyclopedia of Medicine
[32] Foster Miller Associates [1975]: "Design of Reusable Explosion-Proof Bulkheads for a Crosscut Refuge Chamber", National Technical Information Service, PB251714
[33] McCoy JF et al [1983]: "Development of Guidelines for Rescue Chambers, Volume II, Appendices", USBM Contract J0387210 and Kravitz JH [1981] "An examination of Major Mine Disasters in the United States", MSHA and US Mine Rescue Association [2006]: "Mine Disasters Since 1980", www.usnra.com and CDC [2004]: "Analysis of Mine Fires for all Underground and Surface Coal Mining Categories: 1990-1999", IC 9470

where miners who had barricaded were affected by secondary explosions or fires. The instances where secondary explosions had cost lives predominately have been the lives of fellow miners or rescue team members who entered areas where methane levels were building without adequate ventilation. Additionally, the Task Force did not conclude that barricading in emergency shelters/chambers would allow survival from a major mine fire in the immediate area. Experience demonstrated that if a coal mine fire cannot be contained within a few hours after discovery, the chances of successfully extinguishing the fire without sealing part of the mine or the entire mine are greatly diminished[34]. Given these realities, the Task Force recommends that the shelter/chamber be designed to survive an initial event.

The Task Force concluded that the shelter/chamber needs to be sized to support a number equal to or exceeding the total number of miners reasonably likely to be in that area.

Based upon this scenario it was necessary to define the pressure threshold for survival of the emergency shelter/chamber during the initial event. Pressures referred to in regulations and rules for mine stoppings and seals are for static pressure. Static pressure is the force per unit area exerted across a surface parallel to the direction of the flow.[35] In an explosion, static pressure increases rapidly then returns to normal. This sudden increase in pressure is referred to as peak overpressure. The overpressurization wave from a methane explosion in a mine is a function of the concentration of the methane and the length of the area in which the reaction occurs. As the flame front moves through the gas, it increases the temperature of the reaction products it leaves behind. The hot gases expand pushing the flame-front much like a piston in a cylinder.

[34] Conti RS [2006]: "Responders to Underground Mine Fires", NIOSH Pittsburgh Research Laboratory
[35] http://en.wikipedia.org/wiki/Pressure

Turbulence is created by imperfections in the ribs, roof and floor and varying methane concentration between floor and roof. Studies by the US Bureau of Mines found that a typical 25 foot flame-front generates a 15 psi overpressurization wave with one second duration[36]. As the flame-front passes a crosscut, a portion of its energy is transferred along these paths reducing the pressure in the forward direction. In addition, as the pressure front moves it loses pressure as a result of friction with ribs, floor and ceiling.

The Task Force's scenario assumes that miners are within 1,000 feet of a methane explosion. Each crosscut that the blast passes reduces its pressure by 1/3, therefore, if it were 15 psi before a cross-cut it would be 10 psi afterward[37]. The additional loss from surface friction is 33% per 100 feet traveled[38]. We also found that Department of Defense weapon designers use a 13 psi peak overpressure as the 100% lethality threshold[39]. Blast injury occurs from an interaction of the overpressurization wave and the body with differences occurring from one organ system to another. Air-filled organs such as the ear, lung, gastrointestinal tract and organs surrounded by fluid-filled cavities such as the brain and spinal cord are especially susceptible to overpressure blast injury[40]. The overpressurization wave dissipates quickly, causing the greatest risk of injury to those closest to the explosion[41]. It is thus possible that because of the turbulent nature of the pressure, some survivors could benefit from emergency shelter/chamber

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[36] Mitchell, DW and Nagy J [1963]: "Experimental Coal Dust and Gas Explosions", US Bureau of Mines, RI 6344
37 GexCon AS: "Gas Explosion Handbook", http://www.gexcon.com/index.php?src=handbook/GEXHBchap1.htm
[38] Mainiero, RJ and Weiss ES [1983]: "Blast Wave Propagation in Underground Mines", USBM Pittsburgh Research Laboratory
[39] US Naval graduate school [2006]: "Introduction to Naval Weapons", http://www.fas.org/man/Department of Defense-101/navy/docs/es310/syllabus.htm
[40] Elsayed, N. M. (1997). Toxicology of blast overpressure. *Toxicology, 121*, 1-15.
[41] Mayorga, M. A. (1997). The pathology of primary blast overpressure injury. *Toxicology, 121*, 17-28.

installations. The Task Force thus determined that a 15 psi overpressurization wave for a shelter/chamber located in a crosscut 500 feet but no more than 1,000 feet from a working face explosion would likely survive for use by miners who find they could not escape.

The Task Force also considered dynamic pressure. Dynamic pressure is the pressure increase that a moving fluid imparts upon an object in its path and is expressed as the velocity of that object. A 1/16 inch square rock particle would be accelerated by the explosion of 1,000 cubic feet of 10% methane to 1,500 feet per second.[42] It is unlikely that even the most robust shelter/chamber could survive such conditions. Using the same logic as MSHA uses for seal limits the Task Force recommends that shelter/chambers be positioned in crosscuts in order to avoid much of the dynamic pressure.

Temperature thresholds were predominately developed based upon the discussions with SCSR manufacturers and NIOSH that revealed the maximum temperature at which catastrophic failures were observed were in the 150 °F to 300°F range[43]. Most emergency shelter/chamber manufacturers appear to be offering oxygen supply in the form of compressed gas or chemical generation processes similar to those used by SCSR manufacturers. It was also learned that the irreversible damage threshold for human skin is 170°F for 1 second[44]. Methane combustion generates temperatures at the flame front exceeding 2,500°F with the front moving at

[42] v(at 100 m) = (2150 m/s) $e^{-(1.2 \times 0.5 \times 0.0001 \times 100)/(2 \times 0.002)}$ = 480 m/s - Fragment velocity at 100 m from the detonation given: A = 1 cm^2 C_d = 0.5 m = 2 g with the default value for the density of air.
[43] Interviews with NIOSH scientists and CSE, Drager, and Ocenco technical personnel [April 2006]
[44] Clarke J [1999]: "Burns" Brit Med Bull 1999; 55: 885-894 and Koumbourlis A C [2003]: "Electric injuries" Crit Care Med; 30 (Suppl 11): S424-430.

approximately 100 feet per second[45]. While the flame would quickly pass, the resultant convective and irradiative heat would likely exceed the skin damage thresholds by at least a factor of two resulting in deep 2nd and 3rd degree burns[46]. The Task Force concluded that a flash temperature of 300 °F would ensure that the shelter would survive an initial event.

It does little good if the shelter survives the initial event but the environment inside will not support the lives of any miners who may not be able to escape. In considering interior environmental criteria, the Task Force adopted existing NIOSH, MSHA, and WV MHS&T guidelines of oxygen, carbon dioxide, and carbon monoxide. For temperature we found general consensus among Department of Defense, NATIONAL AVIATION AND SPACE ADMINISTRATION, Canadian, Australian, and United Kingdom guidance for an 'apparent-temperature' of 95°F [47]. The largest technical challenge in maintaining this temperature is the approximately 400 BTU per hour per miner that will be generated while the shelter/chamber is occupied[48]. Each BTU per hour represents the energy required to raise the temperature of one pound of water by one degree Fahrenheit. Potentially high temperatures are compounded by high humidity in a sealed environment. High humidity reduces the ability of the body to regulate

[45] University of South Australia, School of Engineering [2003]: "Gas, dust, spontaneous combustion & outbursts"
[46] Wilcox R [1996]: "The realities of explosive thermal radiation", http://www.explosafety.homecall.co.uk/art1pt3.htm and Burnsurgery.org [2006]: "Section II: Pathogenesis of burn injury (initial and delayed)",
[47] Apparent temperature is an adjustment to the dry bulb temperature based on the level of humidity. It is computed using $AT = Ta + 0.33 \times e - 4.00$ where Ta = Dry bulb temperature (°C) and e = Water vapor pressure with the water vapor pressure calculated from the dry bulb temperature and relative humidity using the equation: $e = rh / 100 \times 6.105 \times \exp(17.27 \times Ta / (237.7 + Ta))$ with rh being the relative humidity in percent
[48] NATIONAL AVIATION AND SPACE ADMINISTRATION [2004]: "Manned Systems Integration Standards" http://msis.jsc.National Aviation and Space Administration.gov/Volume1.htm

temperature by sweating thus raising the internal body temperature to the danger range[49]. Several studies report deaths as the result of elevated temperatures in enclosed spaces.[50]

The Task Force set criteria in others areas it concluded appropriate. The Task Force recommends that the emergency shelter/chamber be able to maintain its acceptable environment while allowing miners to enter and exit as needed. The Task Force recommends that the shelter/chamber provide a means to readily identify where it is and if it is occupied. The Task Force concludes it should provide a means of monitoring both the inside and outside air quality and provide a means of signaling the surface. Regarding food and water, the Task Force looked to various Department of Defense, NATIONAL AVIATION AND SPACE ADMINISTRATION, and other sources for minimum sustainable levels. Regarding sanitation the Task Force recommends removal verses chemical treatment. In maintainability, the Task Force recommends that the shelter/chamber be transportable, readily inspected, and contain supplies for its repair while occupied. The Task Force concluded it should be provided with appropriate first aid supplies. And lastly, because it will only be used in the case of an emergency, where applicable, anything in or associated with the shelter/chamber be MSHA certified intrinsically safe or explosion proof.

The Task Force views emergency shelters/chambers as a system. The system includes the materials that physically are in the shelter/chamber, the emergency rescue plan that includes the shelter, and the training for miners and rescue teams in the use of the shelter as a 'last resort'.

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[49] Brenkley BJ et al [2003]: "Use of Self-Rescuers in Hot and Humid Mines", UK Mines Rescue Service; Research Report 180

[50] Brake, DJ and Bates, GP [1999]: "Criteria for the Design of Emergency Refuge Stations for Underground Metal mines", AusIMM Proceedings, No. 2 1999

For that reason, the Task Force also recommends that shelters be incorporated in all aspects of safety, prevention, response planning, and training. All training shall be recorded and made available upon request.

DEFINITIONS

- **Emergency Shelter/Chamber** – An enclosed space located within 1,000 feet of the nearest working face with all sides made from man-made materials whose function is to protect the occupants from hazardous gases.

REQUIREMENTS

Based upon the Task Force's scenario it is recommended that in order to be approved the Director determine that each proposed emergency shelter/chamber:

- provide a minimum of 48 hours life support (air, water, emergency medical supplies, and food) for the maximum number of miners reasonably expected on the working section;
- be capable of surviving an initial event with a peak overpressure of 15 psi and a flash temperature of 300 degrees Fahrenheit;
- be constructed such that it will withstand normal handling and pre-event mine conditions;
- provide for rapidly establishing an internal shelter atmosphere of

  O_2 above 19.5%,

  CO_2 below 0.5%,

  CO below 50 ppm, and

  an apparent-temperature not exceeding 95 degrees Fahrenheit;

- provide the ability to monitor carbon monoxide and oxygen inside and outside the shelter/chamber;
- provide a means for entry and exit that maintains the integrity of the internal atmosphere;
- provide a means for intrinsically safe power if required;
- provide a minimum of eight quarts of water per miner;
- provide a minimum of 4000 calories of food per miner;
- provide a means for disposal of human waste to the outside of the shelter/chamber;
- provide a first aid or EMT kit in addition to a section first aid kit;
- have provisions for inspection of the chamber/shelter and contents;
- contain manufacturer recommended repair materials;
- provide a battery-powered internal strobe light visible from the outside indicating occupancy;
- provide a means of communications to the surface; and
- only contain MSHA approved materials where applicable.

COMMERCIAL AVAILABILITY

The Task Force has reviewed multiple shelter/chamber designs and has determined that products able to meet these standards are currently available for the Director's evaluation.

OPTIONS REVIEWED

Built-in-Place

A built-in-place shelter is a barricade that utilizes the mine as part of its construction (for example enclosing a crosscut). The Task Force reviewed several documents produced during the 1970's and 1980's by the US Bureau of Mines regarding the use of built-in-place shelters using areas, i.e. crosscuts in a mine.

Some Task Force members wanted to prohibit the use of built-in-place shelters in the State of West Virginia, while other Task Force members wanted to allow the use of built-in-place shelters as an option to provide equivalent protection to a shelter/chamber.

The Task Force discussed this issue many times throughout its deliberations and could not reach a consensus.

Hard-Walled

The Task Force reviewed many designs including some prototypes for chambers constructed with hard walls. Most were made of steel, however, some innovative designs included composites and other materials. They are either ready to enter or require minimal assembly if miners find they can not escape.

Soft-Walled

The Task Force reviewed a lesser number of soft-walled chambers. These would be stored in some manner for protection prior to an event and would only be deployed if the miners were unsuccessful in escaping.

Internal Subsystems

Manufacturers differed in their approaches to provide an acceptable atmosphere inside their chambers. Many utilized compressed air or oxygen with some using chemical oxygen production. They all utilized some form of chemical carbon dioxide removal and carbon monoxide removal. Several have attempted to address the temperature control issue without using battery power and the Task Force has confidence they will succeed. The Task Force has encouraged manufacturers to find as many ways as possible to eliminate dependence on electricity from batteries as they introduce the chance of failure in a chamber that may sit for years without use. Several have made significant strides toward this as their designs evolve.

IMPLEMENTATION, COMPLIANCE AND ENFORCEMENT

1. The Director shall require, in each underground mine, an emergency shelter/chamber, it shall be located in a crosscut no more than 1,000 feet from the nearest working face and shall be accurately located on mine maps.
2. The Director may approve, as an alternative to a shelter/chamber, an additional surface opening located no more than 1,000 feet from the nearest working face and accurately located on mine maps.
3. The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support needed to evaluate the performance of emergency shelter/chamber components/systems, and to review the effectiveness of emergency shelter/chamber plans.

4. The Director shall, no later than July 10, 2006, issue an open opportunity for emergency shelter/chamber providers to submit products for approval.
5. The applicant is to submit documentation including a certification by an independent licensed professional engineer that its unit meets the requirements.
6. The Director shall maintain a current list of approved emergency shelter/chambers on the West Virginia MHS&T web site.
7. After an emergency shelter/chamber has been approved, any modifications must be submitted for approval by the Director.
8. The Director shall convene the Mine Safety Technology Task Force not less than once per month through June 30, 2007 for the purpose of reviewing progress by manufacturers, regulators, and operators toward achieving the goals set forth in SB-247 and to review the functional and operational capability of necessary mine safety and health technologies. The Task Force shall submit a report to the Director of its findings and recommendations.
9. No later than April 15, 2007 all underground mine operators shall submit an emergency shelter/chamber plan for approval by the Director. The design, development, submission, and implementation of the shelter/chamber plan shall be the responsibility of the operator of each mine.
10. Within thirty (30) calendar days after submission of the emergency shelter/chamber plan, the Director shall either approve the emergency shelter/chamber plan or shall reject and return the plan to the operator for modification and resubmission, stating in detail the

reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

11. Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its emergency shelter/chamber plan a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the emergency shelter/chamber and for installation and ongoing maintenance.
12. After the Director has approved an operator's emergency shelter/chamber plan, the operator shall submit revisions to the emergency shelter/chamber plan at any time that changes in operational conditions result in a substantive modification. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the emergency shelter/chamber plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.
13. If the Director, in his sole discretion, determines that an operator has failed to provide an emergency shelter/chamber plan, has provided an inadequate emergency shelter/chamber plan, has failed to comply with its approved emergency shelter/chamber plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the

Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

14. In developing the emergency shelter/chamber plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, advances in emergency shelter/chamber technologies and any other aspect of the particular mine the operator deems relevant to the development of the emergency shelter/chamber plan.

15. A copy of the approved emergency shelter/chamber plan shall be provided to the mine rescue teams providing coverage for the mine. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above parties.

16. The proposed emergency shelter/chamber plan shall:
    - describe the structure and operations of the emergency shelter/chamber and its role in emergency response;
    - ensure that emergency shelters/chambers are included in initial mine hazard training in such a manner that it is in compliance with all manufacturer's requirements and is provided yearly in addition to annual refresher training. All training shall be recorded and made available upon request;
    - ensure weekly inspections of emergency shelters/chambers and contents shall be conducted by a certified mine foreman/fireboss and recorded in weekly ventilation examination book;

- ensure that weekly safety meetings review the current location of applicable emergency shelters/chambers and results of the latest inspection;
- ensure that emergency shelters/chambers shall be equipped with easily removable tamper-proof tags such that a visual indication of unauthorized access to the emergency shelter/chamber can be detected; and
- ensure that the mine's communication center shall monitor any communication systems associated with the emergency shelter/chamber at all times that the mine is occupied.

17. The proposed emergency shelter/chamber shall include the ability to:
    - provide a minimum of 48 hours life support (air, water, emergency medical supplies, and food) for the maximum number of miners reasonably expected on the working section;
    - be capable of surviving an initial event with a peak overpressure of 15 psi and a flash temperature of 300 degrees Fahrenheit;
    - be constructed such that it will be protected under normal handling and pre-event mine conditions;
    - provide for rapidly establishing an internal shelter atmosphere of

      O_2 above 19.5%,

      CO_2 below 0.5%,

      CO below 50 ppm, and

      an 'apparent-temperature' of 95 degrees Fahrenheit;

- provide the ability to monitor carbon monoxide and oxygen inside and outside the shelter/chamber;
- provide a means for entry and exit that maintains the integrity of the internal atmosphere;
- provide a means for intrinsically safe power if required;
- provide a minimum eight quarts of water per miner;
- provide a minimum of 4000 calories of food per miner;
- provide a means for disposal of human waste to the outside of the shelter/chamber;
- provide a first aid or EMT kit in addition to a section first aid kit;
- have provisions for inspection of the shelter/chamber and contents;
- contain manufacturer recommended repair materials;
- provide a battery-powered internal strobe light visible from the outside indicating occupancy;
- provide a means of communications to the surface; and
- only contain MSHA approved materials where applicable.

18. The Director may require modifications to an emergency shelter/chamber approval or an emergency shelter/chamber plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.

IV. COMMUNICATIONS AND TRACKING

SUMMARY

In completing its charge to evaluate availability, functional and operational capacity of required communication and tracking devices, the Task Force reviewed multiple products, designs, and approaches and has determined that while no single product exists to meet all the requirements, the intent of SB-247 can be met in most if not all mines by employing separate systems, possibly requiring one for communications and one for tracking.

Further, the Task Force has determined that through utilizing multiple products and procedures an integrated communication/tracking system can be installed that would meet the intent of the law ... 'to protect miners in an emergency'.

Given the recent focus by our nation's technical and scientific community concerning this issue, the Task Force feels that with heightened oversight, continued and substantial progress can be realized.

The Task Force believes that West Virginia must continue its leadership role for emerging mine safety and health technologies by providing a monthly report of communication/tracking progress to insure development and implementation at the earliest possible opportunity.

BACKGROUND

In the aftermath of a catastrophic accident in an underground coal mine, lack of information severely inhibits decision making both for those underground trying to escape and those on the surface trying to respond. This lack of accurate information in the face of life-and-death decision making is a problem the military refers to as the 'fog of war'. The current focus on communications and tracking technologies seeks to reduce this fog.

The proliferation of technologies has encouraged a belief that any problem can be fixed with the right device. This mind set has carried over to a regulatory world where 'people's safety is addressed exclusively in engineering terms'[51] this means that human volition has been left out of the equation. We believe this to be unsound. For this reason, we have taken a look at how miners have made decisions in emergency situations.

As part of this effort, the Task Force considered the experiences of its members and others in underground mine accidents and reviewed studies on past mine accidents.

Several insights relevant to setting communication/tracking system requirements emerged. First, emergency activities (including escape) are not individualistic. They tend to be group responses. Therefore, models based on assumptions of individual behavior are inadequate for setting requirements. Second, leaders have a significant impact on people's perceptions and subsequent behavior. Thus, they greatly influence the groups' survival chances. Third, individuals will assist others, even at their own peril. Fourth, informal groups emerge for dealing with non-routine situations. Finally, team decision-making becomes more common under conditions of stress, even among groups that do not encourage teamwork. [52]

[51] Sime J [1985]. Environ and Behav 17(6):697-724
[52] Vaught C et al [2000]. NIOSH Information Circular 9450

Other valuable reference points are the elements of decision making itself; (1) the recognition of a problem, (2) a definition or diagnosis, (3) consideration of options, (4) a choice of what is perceived to be the best option given what is know and (5) execution of the decision.[53]

Simply installing technologies, however, will not eliminate the possibility that a wrong decision may be made under extreme stress. Experience has demonstrated that the greater the stress, the more often data will be ignored, noise will be mistaken for information and information will be misconstrued, thus increasing the possibility for confusion. Emergency communication/tracking system designs must be well thought through. They must be tailored to the geology and operation of the mine and integrate not only hardware but procedures and include experiential training to ensure success.

In its deliberation the Task Force reviewed advanced devices and systems from dozens of vendors. It concluded that although no single device or system presented had all the functional and operational capability for a combined communication/tracking system that satisfies all the requirements set out in SB-247, there is the potential for adapting many of the more advanced communication and tracking technologies to the underground mine environment. Discussions with manufacturers and vendors indicated that attempts to do so have been stymied by the small market size and the high cost of product development and certification. The Task Force found that there has been little progress in mine communication and tracking technology since the disbandment of the US Bureau of Mines communication efforts in the late 1980's. In fact many of the 'new' approaches presented were adaptations of approaches described by the USBM.

[53] Flathers GW et al [1982] Aviat Space Environ Med 53(10):958-963

Therefore, the Task Force recommends that a responsible agency be once again charged with advancing mine communication/tracking technology.

The Task Force believes that rather than the simple selection of a device, miners are best served by the creation of a mine-specific integrated communication/tracking system that provides them the ability to better understand what is happening around them, to communicate with other members of any groups they form in efforts to escape, to communicate with those on the surface to exchange information, to allow those on the surface information as to miners' location that will reduce the time required for rescue if required, and that such systems incorporate as many redundant options as practical to insure survivability. Additionally, the Task Force believes it is critical that all expected participants in the emergency response have knowledge of the capabilities and limitations of the system as installed and have been exposed to experiential training on its use in group decision-making.

DEFINITIONS

- **Emergency communications** – transmission and reception of data and/or information regarding an unexpected event requiring immediate action, including but not limited to voice, text, signal beacons, etc.
- **Wireless** – allowing individual emergency communications with a mine communication system without a physical connection
- **Communication device** – a piece of equipment that is a component of an integrated mine communication/tracking system

- **Physical location** – position in relation to a tracking device at a known location to enhance rescue and communication with miners during an emergency
- **Tracking & location** – knowing the physical position of miners at the moment of the event and as the event progresses if the tracking/location system being used is still functional
- **Tracking/locating device** - a piece of equipment that is a component of an integrated mine communication tracking system for the purpose of providing the physical location of a miner during an emergency

REQUIREMENTS

Each underground mine shall provide an integrated communication/tracking system, a component of which shall be a communication center monitored at all times during which one or more miners are underground. This center shall be staffed by persons holding a valid underground miners certificate, and trained and knowledgeable of the installed communications/ tracking systems, monitoring and warning devices, travel-ways, and mine layout.

Individuals not possessing a valid underground miner's certificate but working full-time as a communication center operator on or before May 25, 2006 shall be allowed to continue as communications center operators at that mine provided they will have successfully completed no later than December 31, 2006, a certified 80-hour underground miners training program and documentation of training is available for inspection.

The communication/ tracking system shall provide the ability for:

- knowing the location of all miners immediately prior to an event by tracking/locating in the escapeways, normal work assignments, or notification of the communication center;

- knowing the location of miners in the escapeways after an event, providing the tracking system is still functional;
- check-in and check-out with the communication center by persons prior to entrance and exit from bleeders and remote or seldom used areas of the mine (all times shall be logged);
- allowing two way communications coverage in at least two separate air courses, one of which being an intake;
- maintaining communication/tracking capabilities with loss of outside power and maintain function both inby and outby of the event site with suitable supply of equipment for rapid reconnection;
- maintain a surface supply of communication/ tracking devices for use by emergency rescue personnel; and
- allow for communication to surface at all required shelter/chambers.

All mine personnel shall be trained in the use, limitations and inter-operability of all components of the communication and tracking/locating system. All training shall be recorded and made available upon request.

The description and operations of the integrated communication/tracking system and its role in emergency response specific to the mine shall be detailed and submitted to the Director and to the mine rescue teams providing coverage for the mine once approved. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to all the above.

COMMERCIAL AVAILABILITY

In completing its charge to evaluate commercial availability and functional and operational capacity of required devices, the Task Force reviewed multiple communication and tracking products, designs, and approaches and has determined that no single product exists to meet all the requirements of a combined communication/tracking system outlined in SB-247. However, the Task Force has determined that products are available to install separate systems, one for communication and one for tracking. Further the Task Force has determined that through utilizing multiple products and procedures an integrated communication/tracking system can be installed that would meet the intent of the law…to 'protect miners in an emergency'.

Although the environment of underground mines presents physical challenges that impose severe limitations to communications options available on the surface, the Task Force has determined that development of options for underground communication and tracking have been held back primarily by the small size of the potential market. The potential sales volume does not warrant the costs of product development and obtaining the required approvals.

The Federal government has traditionally supported the development of critical technologies in areas where there is a public need and the free market can not respond. Millions of dollars have been spent in developing technologies for markets with limited volumes in the energy industry such as the advanced seismic exploration of oil and gas, advanced combustion turbines for power generation, nuclear power, advanced hot gas cleanup systems for boilers, but none for advancement of coal mine technology. The only instances the Task Force found where Federal funds where used to advance mine communication and tracking products to market in the last 20 years were two projects funded by the US Department of Energy under an energy efficiency program.

With the reductions in funding of the US Bureau of Mines (USBM) starting in mid 1980's and its eventual termination in the 1990's, all efforts to advance mine technology, not just communications and tracking, basically ended in the United States. The cooperative research and development approaches developed under the USBM were successfully adopted by the US Department of Energy and applied to the Clean Coal Technology program and natural gas and oil exploration and production. However, no serious effort has been made by the Federal government to encourage industry to develop or adapt technologies to coal mining.

The Task Force believes that West Virginia should exert the credibility gained through its leadership role in mine health, safety, and training to define a Federal/State partnership that will formalize a program for continuous development of mining technology. Such a program should leverage funding from states with federal dollars to address solutions that are based upon the needs identified by state mine offices in consultation with federal agencies. The program should utilize the Small Business Innovative Research (SBIR) model to seek alignments between mining needs with those of Department of Defense, NATIONAL AVIATION AND SPACE ADMINISTRATION, DOE, etc. The SBIR model solicits solutions from small business for well-defined agency needs. The process has well defined phases, provisions for cost sharing, and commercialization goals. State funds could provide added cost-share money to enhance competitiveness of West Virginia proposals and accelerate development. Until such time as such a program can be established, The Task Force recommends that West Virginia initiate a program of its own based upon this model to spur solutions and advance small business innovation in the State.

The Task Force has concerns about the current MSHA approval process applied to communication and tracking which only focuses on explosion prevention and not on functionality and operability. Products that are functionally ineffective and impossible to operate can be certified under the current rules. Therefore, the Director needs a means of ensuring that communication and tracking technologies that are MSHA certified actually work in the West Virginia applications for which they are proposed.

The Task Force recommends that the Office of MHS&T employ or obtain the services of an engineer whose duties would include reviewing communication/tracking technologies, communications/tracking plans, modification requests, provide technical assistance to industry and inspectors, and work to encourage the development or adaptation of communication and tracking technologies to West Virginia's underground mines.

OPTIONS REVIEWED

The Task Force reviewed multiple techniques of communication and tracking. All of them offer some advantages and have some limitations. A summary of the techniques follows.

Through-The-Earth Communications Options

Through the Earth (TTE) communications can take different forms. They include ground conduction, seismic, and wireless. Each type has unique characteristics which may be beneficial under certain emergency situations.

TTE Ground Conduction Signaling - Ground conduction signaling, called "the TPS method" by the U.S. Army Signal Corps[54]; consists of injecting and receiving signals through the ground via ground-stake connections.

TTE Seismic Signaling - Seismic signaling consists of using special sensors called geophones, to pick up vibration signatures created by a miner who pounds on roof bolts, the roof, or floor of the mine. [55]

TTE Wireless Signaling - A portable TTE system will likely have the best chance of providing contact with miners since it offers the best resistance to damage from roof falls, fires, and explosions. However, in this type of system frequency, geology, noise, and depth will influence the probability of successful communication.[56]

Through-The-Air Communications Options

Underground coal mines present unique challenges to radio signal propagation. The electrical properties of coal attenuate certain frequencies more than others. The effectiveness of wireless radio transmission in particular coal mines can only be determined through thorough testing in the mine environment.

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[54] Jakosky, J.J., February 1924, UG Signaling for Mines by the Ground-Conduction or "T.P.S." Method, U.S. Bureau of Mines, RI 2576.

[55] Kononov, Dr. V.A, November 1999, Develop a trapped miner location system and an adequate strategy and associated technologies, CSIR Division of Mining Technology South Africa and Powell, JA and Watson, RA [1976]: "Seismic Detection of Trapped Miners Using In-Ground Geophones", USBM RI-8158 and Greenfield, RJ [1983]: "Improvements to the Seismic Detection and Location Procedure", Penn State Univ, USDI J0318047 and Fowler, JC [1975]: "Seismic Mine Monitor System", Conoco Geophysical, DOI HO133112 and Greenfield, RJ [1982]: "Theoretical Investigation of Seismic Waves Generated in Mines", G-0155044

[56] Emslie, AG et al, Emergency and Operational Mine Communications, Arthur D. Little, U.S. Bureau of Mines Contract Report No. HO122026.

Research has shown that medium frequencies (MF) offer a viable approach to underground coal mine communications under certain circumstances. MF transmission is feasible for both personnel and vehicular communications. It does not suffer the attenuation characteristics and severe corner losses of Ultra High Frequencies (UHF) communications nor does it require the use of leaky feeder cable. Furthermore, it does not experience the high noise levels of low frequency communications. Research has demonstrated ranges of 1000 – 1500 feet in conductor-free areas, and much greater ranges in conductor-filled areas[57]. 300 kHz to 600 kHz (MF) frequencies work well when in the presence of any conductive medium (e.g., wires, cables, tracks, etc.). Radio signals in the 27 MHz range are absorbed by coal seams[58]. Radio signals in the 150, 500, 900 MHz and 2.5 GHz provide good line-of-sight propagation but typically won't turn more than a few crosscuts.[59]

Through-The-Wire Communications Options

All communications and tracking devices eventually connect to a wired system either above or below ground. Through-the-wire (TTW) communications signals travel over twisted pair, CAT5 (Ethernet cable), trolley cables, leaky feeders, and fiber optic cables.[60] Each of these

[57] Aidala, D.A., Lagace, R.L., Emslie A.G, Ginty, J.J., Roetter, M.F., Spence R.H. Welz, A.W. A Survey of EM and Seismic Noise Related to Mine Rescue Communications, Arthur D. Little Inc. U.S. Bureau of Mines Contract Report HO122026.

[58] Curtis, D.A, Lagace, Robert L, Foulkes, J.D., Rothery J.L., May 1977, Feasibility of Developing Efficient Compact Transmit Antennas for Portable VLF to MF Wireless Mine Communications, Arthur D. Little Inc. U.S. Bureau of Mines Contract Report HO346045.

[59] Conti, Ronald, 2000, White Paper on Technologies for Communications and Locating Trapped Miners.

[60] Moussa, Albert, Lagace, Robert L., 1982, February, Initial Study of Buried Communications Cable for UG Mines, U.S. Bureau of Mines Contract Report No. JO3038037.

cable types have unique properties which generally are selected to suit the characteristics of the signals being conveyed. While TTW communication systems provide a large selection of device options and easily transfer signals between the surface and underground, they are susceptible to failure due to fires, explosions, and roof falls. However, with judicious system design and use of redundant wiring designs TTW systems should survive all but the most severe accidents.[61]

Seismic Communications/Tracking Options

Though not generally thought of as a communication system, a seismic location system can locate a miner with an accuracy of 100 feet and can tell a miner his signal has been located. As a miner moves, the path of these signals can track movement during an escape. Research performed in the 1970's by the USBM produced a system and a method which could provide locations of miners to a depth of 2000 feet. Many advances have been made in seismic equipment with current systems operating off a laptop computer. Miners generate seismic signals by pounding on mine surfaces such as the roof, floor, and ribs, but preferably roof bolts. The system can monitor approximately 1 square mile over most mines[62].

Tracking/Location Identification Options

There are multiple means of locating and tracking a miner. One method involves measuring the strength of the signal from a miner's radio in relation to known receivers. Another involves embedding radio-frequency identification (RFID) tags on each miner that

[61] Forbes, J.J, Griffith, F.E., Cash, F.E., Petersen, Max S., March 1946) Mine Rescue Life-line Telephone Assemblies, U.S.Bureau of Mines Report of Investigation 3875.

[62] Lagace, Robert L., Dobbie, James M., Hawes, William S., Detection of Trapped Miner EM Signals Above Coal Mines, U.S. Bureau of Mines Contract Report No. J0188037, July 1980.

transmit data to an RFID receiver of known location. As the miner passes a receiver, it notifies a central system that records the location via a combination of wireless readers interconnected via leaky feeder, WiFi, or other systems. [63]

IMPLEMENTATION, COMPLIANCE AND ENFORCEMENT

1. The Director shall require, in each underground mine, an integrated communication/ tracking system, a component of which shall be a communication center monitored at all times during which one or more miners are underground.
2. The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support to evaluate the performance of individual communication/tracking systems and review the effectiveness of communication/tracking plans.
3. The Director shall convene the Mine Safety Technology Task Force not less than once per month through June 30, 2007 for the purpose of reviewing progress by manufacturers, regulators, and operators toward achieving the goals set forth in SB-247 and other mine health and safety technology to promote the availability, functional and operational capability of necessary mine safety and health technologies. The Task Force shall submit a report to the Director of its finding and recommendations.
4. No later than August 31, 2007 all underground mine operators shall submit a communication/tracking plan for approval by the Director. The design, development, submission, and implementation of the communication/tracking plan shall be the responsibility of the operator of each mine.

[63] Grayson, R.L., Unal, A., April 1998, Evolution of RFID technology in UG Mines, Mining Engineering, pp. 75-80.

5. Within thirty (30) calendar days after submission of the communication/tracking plan, the Director shall either approve the communication/tracking plan, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.
6. Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its plan, a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the communication/tracking system and for installation and ongoing maintenance.
7. After the Director has approved an operator's communication/tracking plan, the operator shall submit revisions to the communications plan at any time that changes in operational conditions result in a substantive modification in the communication/tracking system. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the communications/tracking plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.
8. If the Director, in his sole discretion, determines that an operator has failed to provide a communications/tracking plan, has provided an inadequate communications/tracking plan, has failed to comply with its approved communications/tracking plan, or has failed

to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

9. In developing the communication/tracking plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, existing communication infrastructure, advances in communication/tracking technologies and any other aspect of the particular mine the operator deems relevant to the development of the communication/tracking plan.
10. The proposed communication/tracking plan shall describe the structure and operations of the separate or integrated communication/tracking system(s) and its role in emergency response specific to the mine shall be detailed and submitted to the Director and, once approved, to the mine rescue teams providing coverage for the mine. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above.
11. The proposed communication/tracking system shall include the ability for:
    - a communication center monitored at all times during which one or more miners are underground. This center shall be staffed by persons holding a valid underground miners certificate, and trained and knowledgeable of the installed communications/ tracking systems, monitoring and warning devices, travel ways, and mine layout. Individuals not possessing a valid underground miner's certificate but working full-

time as a communication center operator on or before May 25, 2006 shall be allowed to continue as communications center operators at that mine provided they will have successfully completed no later than December 31, 2006 a certified 80 hour underground miners apprentice training program and documentation is available for inspection;

- knowing the location of all miners immediately prior to an event by tracking/locating in the escape-ways, normal work assignments, or notification of the communication center;
- knowing the location of miners in the escape-ways after an event providing the tracking system is still functional;
- check-in and check-out with the communication center by persons prior to entrance and exit from bleeders and remote or seldom used areas of the mine (all times shall be logged);
- allowing two way communications coverage in at least two separate air courses and at least one of which shall be an intake;
- maintaining communication/tracking after loss of outside power and maintain function both inby and outby of the event site with suitable supply of equipment for rapid reconnection;
- maintain a surface supply of communication/ tracking devices for use by emergency rescue personnel;
- allow for communication to surface at all required shelters/chambers;

- all miners and likely emergency responders shall be trained in the use, limitations and inter-operability of all components of the communication and tracking/locating system. This shall be incorporated into required training. All training shall be recorded and made available upon request;

12. The operator shall provide a schedule of compliance for the communication/tracking plan, which shall include:
    - a narrative description of how the operator will achieve compliance with above requirements;
    - a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and
    - a statement indicating when the implementation of the proposed plan will be complete.
13. The operator shall provide as attachments to its communication/tracking plan:
    - a statement of the analysis and evaluation required in developing its plan;
    - a statement indicating the initial training dates for implementation of the communication/ tracking system and how the communication/tracking system will be incorporated in other required training;
    - a statement regarding how the communications/tracking system will be tested and maintained; and
    - the name of the person or persons representing the operator, including his or her title, mailing address, email address and telephone number, who can be contacted by the

Director for all matters relating to the communication/tracking plan and weekly testing of the system.

V. RELATED SAFETY ISSUES

The Task Force found many related safety and health issues important to miners but was unable to dedicate significant time to any. It provides the following recommendations and will work with the Director and the Board of Coal Mine Health and Safety to better explore these related issues.

LIFELINES

In lieu of installed lifelines in track or belt entries, markers such as floor mats with arrows, fish plate reflectors, red/green lasers shall be installed at distances not to exceed 1,000 feet or line of sight, or other equivalent devices may be used if approved by the Director.

SEALS

'Omega" type blocks shall not be used in future seal construction. They may, however, be used for other type ventilation controls. The Task Force applauds the Director's May 12, 2006 action imposing a moratorium on "Omega" type block installations and MHS&T's ongoing review of all existing installations. It is recommended that immediate corrective action be taken where warranted.

SEISMIC LOCATING DEVICES

The Director shall provide portable seismic locating systems at each regional office for use in locating trapped miners. Each office will maintain a trained staff that shall upon notification from Homeland Security Office, be capable of delivering the system to the mine site and to deploy system immediately and without delay. These persons shall practice with the said systems at least annually at different mine sites.

MINE RESCUE TEAMS

The Task Force supports and applauds the actions taken by the Board of Coal Mine Health and Safety and the Director of the Office of MHS&T for their efforts to address mine rescue capabilities and other mine rescue concerns in the State of West Virginia. The Task Force recommends these efforts be expanded to reflect currently available technology for mine rescue and fire fighting.

All mine rescue teams must participate in at least 2 mine rescue training events that are state or nationally sanctioned each year.

APPENDIX A – SENATE BILL 247 AND THE EMERGENCY RULE

ENGROSSED

COMMITTEE SUBSTITUTE

FOR

Senate Bill No. 247

(By Senators Tomblin, Mr. President, and Sprouse,

By Request of the Executive)

[Originating in the Committee on the Judiciary;

reported January 23, 2006.]

A BILL to repeal §22A-2-69 of the Code of West Virginia, 1931, as amended; to amend said code by adding thereto a new article, designated §15-5B-1, §15-5B-2, §15-5B-3, §15-5B-4 and §15-5B- 5 ; to amend and reenact §22A-2-55 and §22A-2-66 of said code; and to amend said code by adding thereto a new section, designated §24-6-14, all relating to mine and industrial emergencies; creating the Mine and Industrial Accident Rapid Response System; providing requirements for protective equipment in underground mines; providing for criminal penalties for the unauthorized removal of or tampering with certain protective equipment; defining certain terms; providing for notification requirements in the event of an accident in or about any mine and imposing a civil administrative penalty for the failure to comply with such notification requirements; providing rule-making authority; and clarifying the responsibilities of county answering points.

Be it enacted by the Legislature of West Virginia:
That §22A-2-69 of the Code of West Virginia, 1931, as amended, be repealed; that said code be amended by adding thereto a new article, designated §15-5B-1, §15-5B-2, §15-5B-3, §15-5B-4 and §15- 5B-5 ; that §22A-2-55 and §22A-2-66 of said code be amended and reenacted; and that said code be amended by adding thereto a new section, designated §24-6-14, all to read as follows:

CHAPTER 15. PUBLIC SAFETY.

ARTICLE 5B. MINE AND INDUSTRIAL ACCIDENT RAPID RESPONSE SYSTEM.

§15-5B-1. Legislative purpose; Mine and Industrial Accident Rapid Response System created.

(a) The Legislature finds that the health and safety of persons working in and around the mining industry and other industries is of paramount concern to the people of West Virginia and that deaths and serious injuries resulting from dangerous working conditions cause grief and suffering to workers and their families. The Legislature further finds that there is an urgent need to provide more effective means and measures for improving emergency response and communications for dealing with mine and industrial accidents. The Legislature declares that it is in the best interest of the citizens of West Virginia to designate an emergency telephone number for mining or industrial personnel to initiate a rapid emergency response to any mine or industrial accident. Provision of a single, primary emergency number through which emergency services can be quickly and efficiently obtained and through which the response of various state agencies charged by law with responding to mine and industrial emergencies can be coordinated will significantly contribute to the public good. The Mine and Industrial Accident Rapid Response System will provide a vital resource to the citizens of West Virginia by providing a critical connection between the Director of the Office of Miners' Health, Safety and Training, the Division of Homeland Security and Emergency Management, local and regional emergency services organizations and other responsible agencies.

(b) The Mine and Industrial Accident Rapid Response System is hereby created and shall consist of:

(1) The Mine and Industrial Accident Emergency Operations Center established in section two of this article; and

(2) The 24-hour-a-day statewide telephone number established by the Director of the Division of Homeland Security and Emergency Management.

§15-5B-2. Mine and industrial accident emergency operations center.

(a) The Director of the Division of Homeland Security and Emergency Management, working in conjunction with the Office of Miners' Health, Safety and Training, shall maintain the Mine and Industrial Accident Emergency Operations Center, which shall be the official and primary state government twenty-four hour a day communications center for dealing with mine and industrial accidents.

(b) The emergency operations center shall be operated twenty- four hours a day, seven days a week by emergency service personnel employed by the Director to provide emergency assistance and coordination to mine and industrial accidents or emergencies.

(c) The emergency operations center shall be readily accessible twenty-four hours a day at a statewide telephone number established and designated by the Director.

§15-5B-3. Emergency mine response.

(a) To assist the Division of Homeland Security and Emergency Management in implementing

and operating the Mine and Industrial Accident Rapid Response System, the Office of Miners' Health, Safety and Training shall, on a quarterly basis, provide the emergency operations center with a mine emergency contact list: *Provided*, That in the event of any change in the information contained in the mine emergency contact list, such changes shall be provided immediately to the emergency operations center. The mine emergency contact list shall include the following information:
(1) The names and telephone numbers of the Director of the Office of Miners' Health, Safety and Training, or his or her designee, including at least one telephone number at which the Director or designee may be reached at any time;
(2) The names and telephone numbers of all district mine inspectors, including at least one telephone number for each inspector at which each inspector may be reached at any time;
(3) A current listing of all regional offices or districts of the Office of Miners' Health, Safety and Training, including a detailed description of the geographical areas served by each regional office or district; and
(4) The names, locations and telephone numbers of all mine rescue stations, including at least one telephone number for each station that may be called twenty-four hours a day and a listing of all mines that each mine rescue station serves in accordance with the provisions of section thirty-five, article one, chapter twenty- two-a of this code .
(b) Upon the receipt of an emergency call regarding any accident, as defined in section sixty-six, article two, chapter twenty-two-a of this code, in or about any mine , the emergency operations center shall immediately notify:
(1) The Director of the Office of Miners' Health, Safety and Training;
(2) The district mine inspector assigned to the district or region in which the accident occurred;
(3) All mine rescue stations that provide rescue coverage to the mine in question; and
(4) Local emergency service personnel in the area in which the accident occurred.
(c) In the event that an emergency call regarding any accident, as defined in section sixty-six, article two, chapter twenty-two-a of this code, in or about any mine , is initially received by a county answering point, the call shall be immediately forwarded to the Mine and Industrial Accident Emergency Operations Center.
(d) Nothing in this section shall be construed to relieve an operator, as defined in section two, article one, chapter twenty- two-a of this code, from any reporting or notification obligation under federal law.
(e) The Mine and Industrial Accident Rapid Response System and the emergency operations center are designed and intended to provide communications assistance to emergency responders and other responsible persons. Nothing in this section shall be construed to conflict with the responsibility and authority of an operator to provide mine rescue coverage in accordance with the provisions of section thirty-five, article one, chapter twenty-two-a of this code or the authority of the Director of the Office of Miners' Health, Safety and Training to assign mine rescue teams under the provisions of subsection (d) of said section or to exercise any other authority provided in chapter twenty-two-a of this code.
§15-5B-4. Study of other industrial emergencies.

The Director of the Division of Homeland Security and Emergency Management shall immediately cause a study to be conducted to determine the feasibility of providing emergency coverage to other industrial, manufacturing, chemical or other emergencies through the Mine and Industrial Accident Rapid Response System. On or before the first day of November, two thousand six, the Director shall submit a report to the Governor, the President of the Senate and the Speaker of the House of Delegates setting forth the findings of his or her study and recommendations for legislation consistent with the purposes of this article.

§15-5B-5. Rule-making authority.

The Director of the Division of Homeland Security and Emergency Management shall propose emergency and legislative rules for promulgation in accordance with article three, chapter twenty- nine-a of this code regarding the implementation and administration of the Mine and Industrial Accident Rapid Response System. The requirements of this article enacted during the regular session of the Legislature in January, two thousand six, shall not be implemented until the emergency rule authorized herein has been approved.

CHAPTER 22A. MINERS' HEALTH, SAFETY AND TRAINING.

ARTICLE 2. UNDERGROUND MINES.

§22A-2-55. Protective equipment and clothing. (a) Welders and helpers shall use proper shields or goggles to protect their eyes. All employees shall have approved goggles or shields and use the same where there is a hazard from flying particles or other eye hazards.

(b) Employees engaged in haulage operations and all other persons employed around moving equipment on the surface and underground shall wear snug-fitting clothing. (c) Protective gloves shall be worn when material which may injure hands is handled, but gloves with gauntleted cuffs shall not be worn around moving equipment. (d) Safety hats and safety-toed shoes shall be worn by all persons while in or around a mine: *Provided,* That metatarsal guards ~~shall~~ are not ~~be~~ required to be worn by persons when working in those areas of underground mine workings which average less than forty-eight inches in height as measured from the floor to the roof of the underground mine workings. (e) Approved eye protection shall be worn by all persons while being transported in open-type man trips. (f)(1) A self-contained self-rescue device approved by the Director shall be worn by each person underground or kept within his immediate reach and ~~such~~ the device shall be provided by the operator. The self-contained self-rescue device shall be adequate to protect ~~such~~ a miner for one hour or longer. Each operator shall train each miner in the use of such device and refresher training courses for all underground employees shall be held during each calendar year.

(2) In addition to the requirements of subdivision (1) of this subsection, the operator shall also provide caches of additional self-contained self-rescue devices throughout the mine in accordance with a plan approved by the director. Each additional self-contained self-rescue device shall be adequate to protect a miner for one hour or longer. The total number of additional self- contained self-rescue devices, the total number of storage caches and the placement of each cache throughout the mine shall be established by rule pursuant to subsection (i) of this section.

Intrinsically safe battery-powered strobe lights shall be affixed to each cache and shall be capable of automatic activation in the event of an emergency. A luminescent sign with the words "SELF- CONTAINED SELF-RESCUER" or "SELF-CONTAINED SELF-RESCUERS" shall be conspicuously posted at each cache and luminescent direction signs shall be posted leading to each cache. Lifeline cords or other similar device, with reflective material at 25-foot intervals, shall be attached to each cache from the last open crosscut to the surface. The operator shall conduct weekly inspections of each cache, the affixed strobe lights and each lifeline cord or other similar devise to ensure operability.

(3) Any person that, without the authorization of the operator or the director, knowingly removes or attempts to remove any self- contained self-rescue device or battery-powered strobe light, approved by the director, from the mine or mine site with the intent to permanently deprive the operator of the device or light or knowingly tampers with or attempts to tamper with such device or light shall be deemed guilty of a felony and, upon conviction thereof, shall be imprisoned in a state correctional facility for not less than one year nor more than ten years or fined not less than ten thousand dollars nor more than one hundred thousand dollars, or both.

(g)(1) A wireless emergency communication device approved by the director and provided by the operator shall be worn by each person underground. The wireless emergency communication device shall, at a minimum, be capable of receiving emergency communications from the surface at any location throughout the mine. Each operator shall train each miner in the use of the device and provide refresher training courses for all underground employees during each calendar year. The operator shall install in or around the mine any and all equipment necessary to transmit emergency communications from the surface to each wireless emergency communication device at any location throughout the mine.

(2) Any person that, without the authorization of the operator or the director, knowingly removes or attempts to remove any wireless emergency communication device or related equipment, approved by the director, from the mine or mine site with the intent to permanently deprive the operator of the device or equipment or knowingly tampers with or attempts to tamper with the device or equipment shall be guilty of a felony and, upon conviction thereof, shall be imprisoned in a state correctional facility for not less than one year nor more than ten years or fined not less than ten thousand dollars nor more than one hundred thousand dollars , or both.

(h)(1) A wireless tracking device approved by the director and provided by the operator shall be worn by each person underground. In the event of an accident or other emergency, the tracking device shall be capable of providing real-time monitoring of the physical location of each person underground: *Provided*, That no person shall discharge or discriminate against any miner based on information gathered by a wireless tracking device during nonemergency monitoring. Each operator shall train each miner in the use of the device and provide refresher training courses for all underground employees during each calendar year. The operator shall install in or around the mine all equipment necessary to provide real-time emergency monitoring of the physical location of each person underground.

(2) Any person that, without the authorization of the operator or the director, knowingly removes or attempts to remove any wireless tracking device or related equipment, approved by the

director, from a mine or mine site with the intent to permanently deprive the operator of the device or equipment or knowingly tampers with or attempts to tamper with the device or equipment shall be guilty of a felony and, upon conviction thereof, shall be imprisoned in a state correctional facility for not less than one year nor more than ten years or fined not less than ten thousand dollars nor more than one hundred thousand dollars , or both.

(i) The director may promulgate emergency and legislative rules to implement and enforce this section pursuant to the provisions of article three, chapter twenty-nine-a of this code. The requirements of this article enacted during the regular session of the Legislature in January, two thousand six, shall not be implemented until the emergency rule authorized herein has been approved.

§22A-2-66. Accident; notice; investigation by Office of Miners' Health, Safety and Training.

(a) For the purposes of this section, the term "accident" means:

(1) The death of an individual at a mine; (2) An injury to an individual at a mine which has a reasonable potential to cause death; (3) The entrapment of an individual; (4) The unplanned inundation of a mine by a liquid or gas; (5) The unplanned ignition or explosion of gas or dust;(6) The unplanned ignition or explosion of a blasting agent or an explosive; (7) An unplanned fire in or about a mine not extinguished within five minutes of ignition; (8) An unplanned roof fall at or above the anchorage zone in active workings where roof bolts are in use or an unplanned roof or rib fall in active workings that impairs ventilation or impedes passage; (9) A coal or rock outburst that causes withdrawal of miners or which disrupts regular mining activity for more than one hour; (10) An unstable condition at an impoundment, refuse pile or culm bank which requires emergency action in order to prevent failure, or which causes individuals to evacuate an area, or the failure of an impoundment, refuse pile or culm bank; (11) Damage to hoisting equipment in a shaft or slope which endangers an individual or which interferes with use of the equipment for more than thirty minutes; and (12) An event at a mine which causes death or bodily injury to an individual not at the mine at the time the event occurs.

(b) Whenever by reason of any explosion or other any accident occurs in or about any coal mine or the machinery connected therewith, loss of life, or serious personal injury occurs, it is the duty of the superintendent of the mine, and in his or her absence, operator or the mine foreman in charge of the mine to give immediate notice, within fifteen minutes of ascertaining the occurrence of an accident, to the director and the inspector of the district Mine and Industrial Accident Emergency Operations Center at the statewide telephone number established by the Director of the Division of Homeland Security and Emergency Management pursuant to the provisions of article five-b, chapter fifteen of this code stating the particulars of such the accident: *Provided*, That the operator or the mine foreman in charge of the mine may comply with this immediate notice requirement by immediately providing notice to the appropriate local organization for emergency services as defined in section eight, article five of said chapter, or the appropriate local emergency telephone system operator as defined in article six, chapter twenty-four of this code: *Provided, however*, That nothing in this subsection shall be construed to relieve

the operator from any reporting or notification requirement under federal law.
(c) The director shall impose, pursuant to rules authorized in this section, a civil administrative penalty of one hundred thousand dollars on the operator if it is determined that the operator or the mine foremen in charge of the mine failed to give immediate notice as required in this section: *Provided*, That the director may waive imposition of the civil administrative penalty at any time if he or she finds that the failure to give immediate notice was caused by circumstances wholly outside the control of the operator.
(d) If anyone is killed, the inspector shall immediately go to the scene of ~~such~~ the accident and make ~~such~~ recommendations and render ~~such~~ assistance as he or she may deem necessary for the future safety of the men and investigate the cause of ~~such~~ the explosion or accident and make a record. ~~thereof which~~ He or she shall preserve the record with the other records in his or her office. The cost of ~~such~~ the investigation records ~~to~~ shall be paid by the Office of Miners' Health, Safety and Training.~~, and~~ A copy shall be furnished to the operator and other interested parties. To enable him or her to make ~~such~~ an investigation, he or she has the power to compel the attendance of witnesses and to administer oaths or affirmations. The director has the right to appear and testify and to offer any testimony that may be relevant to the questions and to cross-examine witnesses.

CHAPTER 24. PUBLIC SERVICE COMMISSION.

ARTICLE 6. LOCAL EMERGENCY TELEPHONE SYSTEM.

§24-6-14. Notification of mining accidents.

Each county answering point that receives a call reporting an accident in or about any mine shall immediately route the call to the Mine and Industrial Accident Emergency Operations Center created pursuant to section two, article five-a, chapter fifteen of this code.

APPENDIX B – EMERGENCY RULE

EMERGENCY

WEST VIRGINIA LEGISLATIVE RULE

OFFICE OF MINERS' HEALTH, SAFETY AND TRAINING

TITLE 56

SERIES 4

EMERGENCY RULES GOVERNING PROTECTIVE CLOTHING AND EQUIPMENT

§56-4-1. General.

1.1. Scope. -- These emergency rules pertain to the implementation of provisions of West Virginia Code § 22A-2-55, relating to the regulation of protective clothing and equipment worn by persons underground by the Office of Miners' Health, Safety and Training.

1.2. Authority. -- West Virginia Code § 22A-2-55.

1.3. Filing Date. -- February __, 2006.

1.4. Effective Date. -- ____________, 2006.

§56-4-2. Preamble.

2.1. Purpose – The primary goal of section fifty-five, article two, chapter twenty-two-a of the Code is to protect the health and safety of this State's coal miners by requiring minimum standards for the protective clothing and equipment worn by each underground miner. The purpose of these rules is to implement the mandate of section fifty-five, article two, chapter twenty-two-a of the Code by requiring coal mine operators to provide each underground miner with certain protective equipment and by detailing the requirements for such protective equipment. In implementing such mandate, it is recognized that different types of protective equipment may be developed to satisfy the minimum requirements for protective equipment for each mine, depending upon the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and technological advances.

2.1.1. Exiting a mine is the primary escape procedure to be used by miners in the event of an emergency underground. Self-contained self-rescue devices ("SCSRs") are intended primarily to provide miners with breathable air while attempting to exit the mine during an emergency. The secondary purpose of SCSRs, however, is to provide a source of breathable air to miners that cannot exit a mine during an emergency and must await rescue by personnel on the surface. Emergency shelters/chambers also provide a source of breathable air for trapped miners unable to escape from the mine. Wireless emergency communication devices and wireless tracking devices are intended to assist in both directing miners out of an endangered mine and locating trapped miners awaiting rescue by personnel on the surface. In addition to the purposes stated above, the intended purpose of these rules is to establish a regulatory regime enabling the proper implementation of these technologies in West Virginia's underground mines.

§56-4-3. Definitions.

3.1. Unless herein defined, all terms used in this rule shall have the same meaning as they are defined in West Virginia Code §22A-1-2 and West Virginia Code §22A-2-55.

3.2. "Code" shall mean the Code of West Virginia, 1931, as amended.

3.3. "Director" shall herein refer to the Director of the Office of Miners' Health, Safety and Training.

§56-4-4. Mine Safety Technology Task Force.

4.1. Within seven (7) calendar days of the effective date of these rules, the Director shall establish a Mine Safety Technology Task Force to provide technical and other assistance related to the implementation of the new technological requirements set forth in section fifty-five, article two, chapter twenty-two-a of the Code. The task force shall be comprised of three persons from the major employee organization representing coal miners in this state and three persons from the major trade association representing underground coal operators in this state. All actions of the task force shall be by unanimous vote.

4.2. The task force, working in conjunction with the Director, shall immediately commence a study to determine the commercial availability and functional and operational capability of the SCSRs, emergency shelters/chambers, wireless communication devices and wireless tracking devices required hereunder. The task force shall also study issues related to the implementation, compliance and enforcement of the safety requirements contained herein. Additionally, the task force may study related safety measures, including the provision of additional surface openings and/or escapeways in lieu of or in addition to the provision of SCSRs or emergency shelters/chambers. In conducting its study, the task force shall, where possible, consult with, among others, mine engineering and mine safety experts, radiocommunication and telemetry experts and relevant state and federal regulatory personnel.

4.3. The Director, or his designee, shall preside over all meetings of the working group.

4.4. Within ninety (90) calendar days of the effective date of these rules, the task force shall provide the Director with a written report summarizing its findings regarding the commercial availability and functional and operational capability of the SCSRs, emergency shelters/chambers, wireless communication devices, wireless tracking devices and related safety measures required hereunder. The report shall also include the task force's findings and recommendations regarding implementation, compliance and enforcement of the safety requirements contained herein. The report also shall set forth the task force's recommended implementation, compliance and enforcement plans regarding the aforementioned technologies.

4.5. Prior to approving any emergency shelter/chamber, wireless communication device or wireless tracking device pursuant to the provisions of sections 5.4, 8.1, and 9.1 of these rules, respectively, the Director shall review the task force's written report and the findings set forth therein and shall consider such findings in making any approval determination.

§56-4-5. Self-Contained Self-Rescue Devices Provided for Escape from Mines.

5.1. Each person underground shall be provided a SCSR in accordance with the provisions of subdivision (1), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code. In addition, the operator shall provide caches of additional SCSRs or devices providing equivalent protection throughout the mine in accordance with a Storage Cache Plan approved by the Director.

5.1.1. Each SCSR shall be adequate to protect a miner for one (1) hour or longer: Provided, however, That nothing contained herein shall preclude an operator from providing each person underground with a self-rescue device or a SCSR that provides less than one (1) hour of protection that is nevertheless adequate to provide an amount of breathable air sufficient for travel to the nearest storage cache or escape facility: Provided, further: That the total amount of breathable air provided by the operator meets the minimum amount of three (3) hours of cumulative protection contemplated by the provisions of Section 5.1 and Section 5.2.1 of these rules, as well as the minimum protection amounts mandated by the provisions of 5.3.3 and 5.4.3.

5.1.2. Each cache shall be housed in a container constructed of fire retardant material or material treated with a fire retardant paint or laminate and constructed in a manner capable of protecting the self-contained self rescue devices stored therein from damage by fire.

5.1.3. Each operator shall train each miner in the use of the SCSRs employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year. This training shall be in addition to the annual retraining required by MSHA.

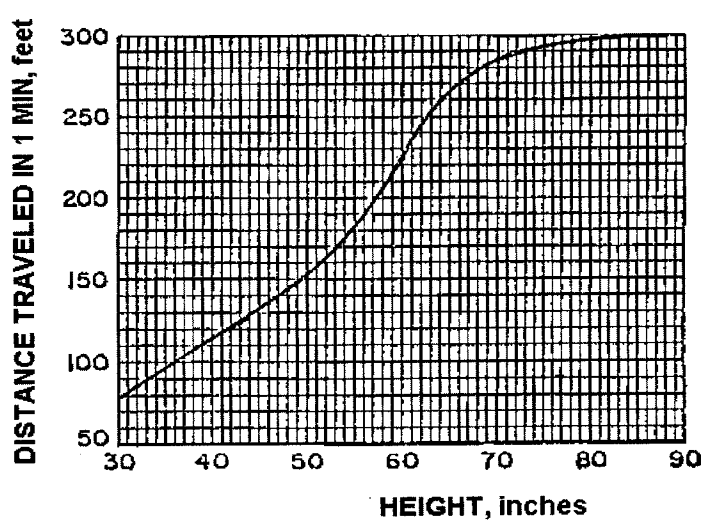
5.2. One cache shall be placed at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine. One cache shall be placed at a readily available location within five hundred (500) feet of each active construction or rehabilitation site within the mine. Distances greater than five hundred (500) feet not to exceed one thousand (1000) feet are permitted, however, where miners are provided with personal SCSRs rated for less than sixty (60) minutes, travel to these caches is not to exceed five (5) minutes as determined by the height/travel time chart as specified in Section 5.3.2.

5.2.1. Each cache placed at each working section and each active construction or rehabilitation site shall contain sufficient additional SCSRs to provide each miner reasonably expected to be at the working section or active construction or rehabilitation site with no less than two (2) additional SCSRs, or an equivalent amount of breathable air for escape. During crew changes involving a mantrip at a working section or an active construction or rehabilitation site, SCSRs stored on such mantrip shall satisfy the total number of SCSRs required for such personnel.

5.3. Additional storage caches shall also be placed in readily available locations throughout the remainder of the mine as follows:

5.3.1. Beginning at the storage cache located at the working section or active construction or rehabilitation site, and continuing to the surface or nearest escape facility leading to the surface, the operator shall station additional storage caches at calculated intervals that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam.

5.3.2. Said intervals shall be calculated in accordance with the following chart:



5.3.3. Each such additional cache shall contain a number of additional SCSRs equal to or exceeding the total number of employees reasonably likely to be in that area.

5.4. Emergency Shelters/Chambers for Use in the Event That Immediate Exit is not Possible.

5.4.1. An emergency shelter/chamber shall be maintained within one thousand (1000) feet of the nearest working face in each working section. Such emergency shelter/chamber shall be approved by the Director and shall be constructed and maintained in a manner prescribed by the Director.

5.4.2. Upon the Director's receipt of the written report required by section 4.4 of these rules, the Director shall review the written report and the findings set forth therein and shall consider such findings in making approval determinations regarding any emergency shelter/chamber.

5.4.3. Any emergency shelter/chamber approved by the Director shall be:

a. equipped to provide each miner at the working section with no less than twenty-four (24) hours of breathable air;

b. constructed in such a manner so as to reasonably exclude dangerous air and gases from the interior of the rescue shelter/chamber;

c. properly equipped with first aid materials;

d. equipped with sufficient amounts of food and water to sustain each miner at the working section for at least twenty-four (24) hours while awaiting rescue;

e. equipped with a device for communication with rescuers or other persons on the surface; and

f. maintained in accordance with applicable MSHA requirements.

5.4.4. As soon as practicable, the Director shall notify all operators of the emergency shelters/chambers approved for use in underground coal mines.

5.4.5. Each operator shall train each miner in the use of the approved emergency shelter/chamber employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year. This training shall be in addition to any annual retraining required by MSHA.

5.4.6. If there are no emergency shelters/chambers approved within one year of the Director's receipt of the task force's report, operators shall install in lieu of an emergency shelter/chamber, caches of SCSRs sufficient to provide each miner reasonably expected to be at the working section with no less than sixteen(16) additional SCSRs, or an equivalent amount of breathable air.

5.4.7. Sixteen (16) SCSRs may be used in lieu of an emergency shelter/chamber when mine design or layout prohibits use of such facilities.

§56-4-6. Storage Cache Plan.

6.1. Within thirty (30) calendar days of the effective date of these rules, all operators of all mines shall submit a Storage Cache Plan for approval by the Director. The design, development; submission, and implementation of the Storage Cache Plan shall be the responsibility of the operator of each mine.

6.2. Within thirty (30) calendar days after submission of the initial Storage Cache Plan, the Director shall either approve the plan as submitted, or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.

6.3. In developing the initial Storage Cache Plan, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine the operator deems relevant to the development of the Storage Cache Plan.

6.4. The Storage Cache Plan shall include the following:

6.4.1. The size and physical features of the mine;

6.4.2. The maximum number of persons underground during each working shift;

6.4.3. The proposed location of the various storage caches and the emergency shelter/chamber in relation to persons underground; and

6.4.4. A schedule of compliance, which shall include:

a. a narrative description of how the operator will achieve compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code.

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when the implementation of the proposed plan will be complete.

6.4.5. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

6.5. Each operator shall submit as attachments to its Storage Cache Plan the following:

6.5.1. A statement that the analysis and evaluation required by section 6.3 of these rules has been completed;

6.5.2. A statement indicating the training dates for the use of the SCSRs; and

6.5.3. The name of the person or persons representing the operator, including his or her title, position, mailing address and telephone number, who can be contacted by the Director for all matters relating to the Storage Cache Plan and the weekly inspections of each cache.

6.6. Within thirty (30) calendar days of the Director's approval of the plan, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such number of additional SCSRs consistent with the operator's schedule of compliance.

6.7. At any time after the Director has approved an operator's Storage Cache Plan, the operator may submit proposed modifications or revisions to its plan along with the reasons therefor to the Director.

6.7.1. Within thirty (30) calendar days after receipt by the Director of any proposed revisions or modifications to the Storage Cache Plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.

6.7.2. The Director may require modifications to a Storage Cache Plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.

6.7.3. Within thirty (30) calendar days of the Director notifying operators of the emergency shelters/chambers approved by the Director under these rules, the operator shall submit a revised Storage Cache Plan in accordance with the provisions of this section setting forth the type of emergency shelter/chamber to be installed pursuant to section 5.4 these rules. The revised storage cache plan shall also include a revised schedule of compliance and information regarding the emergency shelter/chamber that corresponds to the information regarding the storage caches required under this section of these rules.

6.8. If the Director, in his sole discretion, determines that an operator has failed to provide a Storage Cache Plan, has provided an inadequate Storage Cache Plan, has failed to comply with its approved Storage Cache Plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

§56-4-7. Placement of Intrinsically Safe Battery-Powered Lights and Lifeline Cords.

7.1. Intrinsically safe battery-powered strobe lights shall be affixed to each cache of SCSRs and shall operate continuously or be capable of automatic activation in the event of an emergency.

7.1.1. All intrinsically safe battery-powered strobe lights affixed to each cache of SCSRs shall be approved by MSHA and maintained in accordance with applicable MSHA requirements.

7.2. A reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" shall be conspicuously posted at each such cache and reflective direction signs shall be posted leading to each cache.

7.3. Lifeline cords installed in primary escapeways shall be attached to each cache and extend from the last permanent stopping to the surface or nearest escape facility, excluding belt and track entries, and must:

7.3.1. be made of durable material;

7.3.2. be marked with reflective material every twenty-five (25) feet;

7.3.3. be located in such a manner for miners to use effectively to escape; and

7.3.4. have directional indicators signifying the route of escape placed at intervals not exceeding one hundred (100) feet.

7.4. The operator shall conduct weekly inspections of each cache of additional SCSRs, the affixed strobe lights, and each lifeline cord or other similar device to ensure that each will function properly in the event of an emergency.

§56-4-8. Wireless Emergency Communication Devices.

8.1. A wireless emergency communication device approved by the Director shall be worn by each person underground and shall be provided by the operator.

8.1.1. As soon as practicable, the Director shall notify all operators of the wireless emergency communication devices approved by the Director for use by each person underground pursuant to subdivision one, subsection (g), section fifty-five, article two, chapter twenty two-a of the Code.

8.1.2. The wireless emergency communication devices approved by the Director must be capable of receiving emergency communications from the surface at any location throughout the mine.

8.1.3. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

8.2. All wireless emergency communication devices approved by the Director shall have received prior approval by MSHA and be maintained in accordance with applicable MSHA requirements.

8.3. Within sixty (60) calendar days of the Director giving notice of the approved wireless emergency communications devices, all operators shall submit to the Director a schedule of compliance.

8.3.1. The schedule of compliance shall include:

a. a narrative description of how the operator will achieve compliance with subsection (g), section fifty-five, article two, chapter twenty-two-a of the Code;

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when full compliance will be achieved.

8.3.2. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

8.3.3. Within thirty (30) calendar days after submission of the schedule of compliance, the Director shall either approve the schedule of compliance as submitted, or shall reject and return the schedule of compliance to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the schedule of compliance is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such schedule of compliance.

8.3.4. Where applicable, the operator shall submit certified progress reports no less frequently than every sixty (60) calendar days until full compliance is achieved. 8.4. In developing the schedule of compliance, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine and any other aspect of the particular mine relevant to the provision and operation of the wireless emergency communication devices.

8.5. Within thirty (30) calendar days of the Director's approval of the operator's schedule of compliance, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such wireless emergency communication devices consistent with the operator's schedule of compliance.

8.6. If the Director, in his sole discretion, determines that an operator has failed to provide a schedule of compliance, has provided an inadequate schedule of compliance, has failed to meet its approved schedule of compliance or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subsection (g), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

§56-4-9. Wireless Tracking Devices.

9.1. A wireless tracking device approved by the Director shall be worn by each person underground and shall be provided by the operator.

9.1.1. As soon as practicable, the Director shall notify all operators of the wireless tracking devices approved by the Director for use by each person underground pursuant to subdivision one, subsection (h), section fifty-five, article two, chapter twenty two-a of the Code.

9.1.2. The wireless tracking devices approved by the Director must be capable of providing real-time monitoring of the physical location of each person underground, which at a minimum shall mean the capability to identify the presence of each person underground in the event of an emergency.

9.1.3. No person shall discharge or in any other way discriminate against any miner based on information gathered by such wireless tracking device during non-emergency monitoring.

9.1.4. Each operator shall train each miner in the use of the approved device employed at the mine, and refresher training courses for all underground employees shall be held during each calendar year.

9.1.5. The operator shall install in or around the mine any and all equipment necessary to provide real-time emergency monitoring in accordance with the provisions of section 9.1.2 of these rules.

9.2. All wireless tracking devices approved by the Director shall have received prior approval by MSHA and be maintained in accordance with applicable MSHA requirements.

9.3. Within sixty (60) calendar days of the Director giving notice of the approved wireless tracking devices, all operators shall submit to the Director a schedule of compliance.

9.3.1. The schedule of compliance shall include:

a. a narrative description of how the operator will achieve compliance with subsection (h), section fifty-five, article two, chapter twenty-two-a of the Code;

b. a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and

c. a statement indicating when full compliance will be achieved.

9.3.2. Any such schedule of compliance shall be supplemental to, and shall not sanction noncompliance with, the applicable requirements on which it is based.

9.3.3. Within thirty (30) calendar days after submission of the schedule of compliance, the Director shall either approve the schedule of compliance as submitted, or shall reject and return the schedule of compliance to the operator for modification and resubmission, stating in detail the reasons for such rejection. If the schedule of compliance is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such schedule of compliance.

9.3.4. Where applicable, the operator shall submit certified progress reports no less frequently than every sixty (60) calendar days until full compliance is achieved. 9.4. In developing the schedule of compliance, the operator shall take into consideration the number of employees of the particular mine, the location of the particular mine, the physical features of the particular mine, and any other aspect of the particular mine relevant to the provision and operation of the wireless tracking devices.

9.5. Within thirty (30) calendar days of the Director's approval of the operator's schedule of compliance, the operator shall provide to the Director a copy of any contract, purchase order, or other proof of purchase of such wireless tracking devices consistent with the operator's approved schedule of compliance.

9.6. If the Director, in his sole discretion, determines that an operator has failed to provide a schedule of compliance, has provided an inadequate schedule of compliance, has failed to meet its approved schedule of compliance or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subsection (h), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.

APPENDIX C – MINE SAFETY TECHNOLOGY TASK FORCE PROCESS

The Task Force was established by the Emergency Rules Governing Protective Clothing and Equipment at §56.4.4. The Task Force consists of three persons from the major employee organization representing coal miners and three persons from the major trade association representing underground coal operators in this state. All recommendations contained in this report are unanimously supported by the Task Force members.

James Dean, Acting Director of the West Virginia Office of Miners' Health, Safety and Training, announced March 9, 2006 the names of the Task Force and the group held its first meeting on March 13th. The Task Force met in open public forum with experts from industry, regulators, and academia at five different locations throughout the state, to facilitate public participation in the open public meetings, in addition, representatives of the Task Force visited and reported on visits to vendors, research institutions, and underground mines.

While focused upon the areas addressed in West Virginia Senate Bill 247 and the Office of Miners' Health Safety and Training's Emergency Rules; self-contained self-rescuers, emergency shelters/chambers, wireless communication devices and wireless tracking devices, the Task Force also considered other health and safety issues.

TASK FORCE MEMBERS

Dale Birchfield of Crab Orchard, West Virginia has 35 years of coal mining experience. He is the president of Kingston Resources, a subsidiary of Riverton Coal. His office is located in Kingston, W.Va. and he is responsible for management of the company's underground mine and prep plant operations. He holds degrees from Glenville State College and West Virginia Institute of Technology.

Theodore Hapney of Reedy, West Virginia has 32 years of coal mining experience. He began his career in the coal industry in 1974 and held several positions in underground mines. He is a certified electrician and has served as president of his local UMWA union as well as chairman of the local organization's mine and safety committees and on the COMPAC. He is currently an international representative for the UMWA.

Terry Hudson of Beckley, West Virginia has 31 years of coal mining experience. He is the Safety and Training Director for Appalachian Operations for Peabody Energy and his office is located in Charleston, W.Va. A Marshall University graduate, Hudson has a bachelor's degree in business management and a master's degree in occupational safety and health. Hudson has 27 years as a certified mine foreman and mine rescue team member and trainer. He has oversight for Peabody's safety, compliance, health and emergency preparedness programs in West Virginia and western Kentucky.

Todd Moore of Fairview, West Virginia has 26 years of coal mining experience. He is the Chief Inspector for CONSOL Energy, Northern West Virginia Operations, located in Monongah, W.Va. He is responsible for the company's health and safety programs in that region. Moore's underground experience is in West Virginia and Pennsylvania. He is a certified foreman in both states, and is an experienced mine rescue team member. He is a graduate of Fairmont College with a degree in mining.

Gary Trout of Leivasy, West Virginia has 33 years of coal mining experience. He is an International Health and Safety Representative for the UMWA, served as

District 29 Executive Board Member for 12 years, member of Diesel Commission since 1999. He began his career in the coal industry in 1973 and has held multiple positions in the underground mining industry and is a certified electrician and coal mine safety inspector.

Stephen Webber of Belington, West Virginia has 43 years of coal mining experience. He is retired from the coal mines. He worked in underground coal mines, as Assistant Safety Director and International Executive Board Member for the UMWA International Union. Mr. Webber served as director of the West Virginia Office of Miners' Health, Safety and Training and the director of the Office of Assessment for the U. S. Department of Labor's Mine Health and Safety Administration before retiring in 2003.

Mr. Dean or his designee will function as ex-officio chair of the meetings. Mr. Randall Harris will function as ex-officio technical advisor.

James Dean of Core, West Virginia has 15 years of mining related experience. He is currently acting Director of the Office of Miners' Health Safety and Training. Mr. Dean is on leave as of February 14, 2006 from his position as Director of Extension and Outreach and Associate Director of the Mining Extension Program at West Virginia University. Mr. Dean holds an Associate Degree in Engineering Technology-Mechanical, a Bachelor's degree in Engineering Technology-Mining and a Master's Degree in Engineering of Mines. He is also a Certified Mine Safety Professional (CMSP) through the International Society of Mine Safety and has MSHA IS IU Instructor Certification.

Randall Harris of Logan, West Virginia has 23 years of energy technology related experience. He is an independent engineer specializing in coal related technology development. Prior to his retirement in 2003 he served as Senior Engineer at the US DOE's National Energy Technology Laboratory. His specific areas of expertise include product development and commercialization, worker safety and health, and strategic decision making. Mr. Harris has an undergraduate degree from the University of Florida in nuclear engineering and health physics. He did his graduate studies in engineering management at University of Tennessee and business management thorough the West Virginia University Executive MBA program. He has advanced course work at the Federal Executive Institute, the Naval War College, and Harvard's Kennedy School of Government.

TASK FORCE MEETINGS

The Task Force met a total of 36 full days between March 13 and May 25, 2006.

March 13th the Task Force met in Charleston. The objective of this meeting was to review the directive for the task force, determine a schedule, and share information collected.

March 17th the Task Force met in Charleston. At this meeting the task force focused on shelters.

March 20th, 21st, and 22nd meetings were held in Beckley. During these meetings the Task Force worked on shelters. The Task Force also started discussion on SCSR's.

March 27th and 28th meetings were held at the Charleston offices. Discussion was focused on SCSR's.

March 30th and 31st meetings were held at the Beckley Mine Academy. The task force worked on SCSR requirements and cache plans.

April 17th, 18th and 19th meetings were held at the Ogleby Conference Center in Wheeling. The task force focused on mine chambers and began background briefings on communications.

April 20th and 21st meetings the Task Force attended the Mining Health and Safety Symposium at Wheeling Jesuit University.

April 24th, 25th, 26th, and 27th meetings were held at the MHS&T office in Fairmont. The task force focused on communication and tracking options.

May 1st, 2nd, 3rd, 4th and 5th meetings were at the Holiday Inn Clarksburg with recess to attend the Sago hearings on May 2nd, 3rd and 4th. The meetings focused on developing outlines for initial draft of communication/tracking, chambers, and SCSR storage sections of the report.

May 8th, 9th, 10th, 11th and 12th meetings were held at the MHS&T office in Charleston with recess to attend MSHA rule hearings on May 9th. The focus was on refining the sections drafts and developing the introduction language and appendix materials.

May 16th, 17th, 18th and 19th meetings were held at the MHS&T office in Charleston. The focus was on refining the draft report.

May 22nd, 23rd, 24th and 25th meetings were held at the MHS&T office in Charleston. The focus was on finalizing the contents of the report with the vote on the document held on the 25th.

Organizations consulted and/or whose material was reviewed during Task Force deliberations and writing of this report included:

3M Mining – St. Paul, MN	Related Safety Issues
Air Systems Inc. -	Shelters/Chambers
AmerCable Inc – Houston, TX	Communications/tracking
Becker Electronics – Alrode, Alberton, South Africa	Communications/tracking
BioMarine Rebreathers – Exton, PA	SCSR Shelters/Chambers
British Cave Rescue Council – Great Hucklow, Buxton, Great Britain	Communications/tracking
Camber Corporation – Chantilly, VA	Communications/tracking Related Safety Issues
ChemBio Shelter – Allentown, PA	Emergency shelter/chambers
Conspec – Charleroi, PA	Communications/tracking
Cowan Manufacturing Pty – Warners Bay, Australia	Emergency shelter/chambers
CSE – Beckley, WV & Monroeville, PA	SCSR's Communications/tracking
Cummins Industries – Burleston, TX	Related Safety Issues
DKL International, Inc. – Vienna, VA	Communications/tracking
Delta Electric, Inc. – Logan, WV	Communications/tracking
Defibrillators of WV – Parkersburg, WV	Related safety issues
Dräger Safety Inc – Pittsburgh, PA	SCSR's Communications/tracking
Ekahau, Reston, VA	Communications/tracking
Engineering Seismology Group, Inc – Kingston, Ontario, Canada	Communications/tracking Related Safety Issues
Firesafe Consulting Group -	Shelter/Chamber
Fiber – Tech Industries, Inc.	SCSR Shelter/Chamber
Geosteering Mining Services, LLC -	Communications/tracking
Grace Industries – Fredonia, PA	Communications/tracking
GrafTech – Parma, OH	Shelters/Chambers
Hannah Engineering – Elkins, WV	Communications/tracking
HLS Hard-Line Solutions Inc. – Dowing, Ontario	Communications/tracking
Head Lites Corporation – St. Paul, MN	Other safety issues
Hughes Supply Company – Pax, WV	Communications/tracking
i-Tex Wireless	Communications/tracking
Innovative Wireless Technologies -	Communications/tracking
Instantel Inc.- Ottawa, Ontario, Canada	Communications/tracking Related Safety Issues
John Hawse – Beaver, WV	Emergency shelter/chambers
Ken Air, Inc.– Eighty Four, PA	Emergency shelter/chambers
Kutta Consulting – Phenoix, AZ	Communications/tracking
Lad Mining Ventilation Services – Charleston, WV	Emergency shelter/chambers

Linde Gas, Parkersburg, WV	Emergency shelter/chambers
Marco North America, Inc – Ona, WV	Communications/tracking
Micropore Inc – Newark, DE	Emergency shelter/chambers
Mine Rescue Service Limited, London, Great Britain	Communications/tracking
Mine Safe House LLC – Gilbert, WV	Emergency shelter/chambers
Mine Site Technologies – Rolla, MO	Communications/tracking
MineArc Systems – Fort Worth, TX	Emergency shelter/chambers
Modern Mine Supply, LLC – Huntington, UT	Emergency shelter/chambers
MSHA – Pittsburgh, PA	SCSR's
	Emergency shelter/chambers
	Communications/tracking
National Energy Technology Laboratory	Emergency shelter/chambers
	Communications/tracking
	Related Safety Issues
Nextech Materials – Lewis Center, OH	Emergency shelter/chambers
NIOSH – Pittsburgh, PA	SCSR's
	Emergency shelter/chambers
	Communications/tracking
Northern Light Digital – Toronto, Ontario, Canada	Communications/tracking
Ocenco inc – Pleasant Prairie, WI	SCSR's
O-Two Systems International – Mississauga, Canada	SCSR's
	Related Safety Issues
Predivcate Logic Inc. - Chesapeake, VA	Communications/tracking
RadarFind – Research Triangle Park, NC	Communications/tracking
Rajant Breadcrumb System-	Communications/tracking
Rana-Medical – Winnipeg, Manitoba, Canada	Emergency shelter/chambers
RM Wilson Company – WV, UT, IL	Emergency Shelters/Chambers
Rohmac, Inc – Mount Storm, WV	SCSR's
Shairzal Safety Engineering – Baywater, Australia	Emergency shelter/chambers
Stolar, Inc – Ranton, NM	Communications/tracking
Strata Products Inc – Marietta, GA, Richlands, VA	Emergency shelter/chambers
Time Domain/Concurrent Technologies Corp. -	Communications/tracking
Transtek Inc. – Pittsburgh, PA	Communications/tracking
Tunnel Radio Inc, Corvallis, OR	Communications/tracking
University of Florida – Gainsville, FL	Communications/tracking
University of LEEDS – Great Britain	Communications/tracking
University of Texas – Dallas, TX	Communications/tracking
Varis, Inc – Sudbury, Canada	Communications/tracking
Vital Alert -	Communications/tracking
WebCore Technologies, Inc.	Communications/tracking
West Virginia University – Morgantown, WV	Emergency shelter/chambers
	Communications/tracking
Wholesale Mine Supply – Manor, PA	Communications/tracking

APPENDIX D – ORGANIZATIONAL AND TECHNICAL NATURE OF COAL MINING[64]

To extract coal from an underground mine, a coalbed (or "seam") must be reached from the surface. The term "portal" is generally given to any entrance that provides access to a coal mine. In hilly terrain, such as is found in West Virginia, the coal may "outcrop" on a hillside. This allows direct entry to the coal seam via a horizontal tunnel ("drift") opening. At other locations where there is no outcrop, it may be possible to open a "slope" tunnel that angles down from the surface and intersects with the coal seam. If the seam is too deep for a slope to be feasible, a "shaft" must be constructed. This shaft, which may be 20 ft or more in diameter, is opened vertically from the surface to the coalbed and allows access via a large elevator.

During long-range planning there is a general focus on such essentials as equipment type, deployment, utilization, and haulage. Laying out a mine also involves auxiliary factors including ventilation arrangements, roof support plans, power distribution, and communications. All of these planned systems are incorporated into a "projection map" that is developed by a team of technical specialists. This team will include, at various times, mining engineers, electrical engineers, industrial engineers, and company geologists, among others. The mine map serves the same purpose for a person running an operation that an architect's blueprint serves a building contractor. It provides an overview of the project, shows where features should be located, helps management

[64] Vaught, C [2000]: "Behavioral and Organizational Dimensions of Underground Mine Fires", NIOSH IC-9450

direct crews effectively, and serves as a tool in the planning of everything from maintenance schedules to capital expenditures for major equipment purchases.

Responsibility for translating the long-range plan into day-to-day operations belongs to a mine superintendent. This person is in charge of the overall mine complex, including surface facilities. An assistant superintendent helps the superintendent perform his duties and at some sites oversees all underground operations. At least one general mine foreman reports to the assistant superintendent. This individual directs day-to-day underground operations. For each working shift at the mine, there is at least one shift foreman ("shift boss") who reports to the general mine foreman. The shift boss is in charge of mining related activities including coal extraction and service work. Each production crew in the mine is placed under the direction of a section foreman ("face boss") who manages mining operations on his or her section and who reports to the shift boss. There are also supervisors who oversee specialized support work underground. These foremen manage (1) maintenance, (2) belt installation, (3) supply activities, and (4) track laying and repair. All of these individuals report to the shift boss or the general mine foreman.

If coal is to be mined productively, it must be obtained systematically. This requires the integration of several weekly plans into a smooth limited projection. One of the most important functions of a superintendent and his subordinates is to maintain an effective extraction cycle at the point of production. To do this extraction, plans must incorporate the following factors: (1) a determination of the shift for each section at which coal production will take place, (2) a decision about when the section will be idled so that belt and power moves can be made, (3) the scheduling of regular equipment maintenance, (4) provision for special projects such as the installation of belt head drives, and (5) preparation for any tasks that cannot be accomplished during regular workdays, such as shutting down and repairing the ventilation fan. The better a mine superintendent is at planning for and taking care of all of these details, the more smooth-running and efficient an operation will be.

After entering their portal and reaching the underground workings, a typical production crew will board a self-propelled personnel carrier known as a "mantrip" and travel to their "working section." This is where coal is extracted, and may be miles from the portal. "Working faces" are the individual places on a working section where mining activities take place. Here, sets of parallel tunnels ("entries") are driven through the coal seam following a predetermined plan developed by a mining engineer. Mine entries are 16 to 20 ft wide and as high as the coal seam is thick. The number of entries being mined in a working section varies from 2 to 10 or more depending on many factors. As parallel entries are developed, they are connected by perpendicular tunnels ("crosscuts"). Like entries, crosscuts are also usually 16 to 20 ft wide and as high as the coal seam is thick. Crosscuts, or "breaks" as they are sometimes called, allow workers and equipment to move between and among the entries. The walls of entries and crosscuts are called "ribs," while the ceiling above is called the "roof" or "top." The mine floor is typically called a "bottom."

As coal is mined, a working section advances toward the boundaries of the coal property. This advancement is generally known as "development mining" and follows a "room-and-pillar" mining plan. With a room-and-pillar plan, entries and crosscuts are opened through the seam while large blocks of coal ("pillars") are left in place to help support the mine workings. In the United States, most development mining following a room-and-pillar plan uses "continuous mining" technology. Work crews on a continuous mining section are usually composed of 8 to 10 individuals. A typical crew might consist of (1) one face boss, (2) one continuous miner operator and a helper, (3) two roof bolting machine operators, (4) two shuttle car operators, and (5) one mechanic. These workers perform two operation cycles at the working face that include (1) cutting and loading of coal and (2) support of the mine roof above the entry or crosscut.

With continuous mining, operations progress sequentially at each face on a working section. First, an area from which coal has already been extracted (commonly called a "cut") must have its roof supported. The roof is "bolted" by one or two miners who operate a "roof bolter." The roof bolter is a rubber-tired, electrically powered machine with rotating drill heads. It puts holes in the mine roof. Steel bolts (48 to 96 inches long) are then inserted into these holes and tightened. They bind together layers of rock strata located above the cut. This, in effect, creates a supporting beam between coal pillars and across entries and crosscuts. Thus, the roof is prevented from collapsing. Next, a "continuous miner" is "trammed" into the face. A continuous miner is an electrically powered machine that moves along on crawler tracks similar to bulldozer treads. The machine has a rotating drum ("ripper head") about 10 ft wide and 3 ft in diameter, on which cutting bits are mounted. The ripper head rotates and cuts coal from the face. A pair of mechanical gathering arms, located beneath the ripper head, then sweeps the dislodged coal onto a short conveyor. This conveyor moves the coal to the rear of the machine, where it is dumped into a shuttle car (or "buggy"). A buggy is a rubber-tired electrically powered haulage vehicle that can carry 6 to 10 tons of coal. Usually, two buggies transport coal from the face to a conveyor belt dumping point. From this dumping point on the working section, coal is typically transported out of the mine via a series of conveyor haulage belts. In some mines, however, coal is dumped directly into small rail cars. Groups of these cars, known as "trips," are pulled by electrically powered locomotives to a main underground dumping point. From there, the coal is transported out of the mine via conveyor belt.

Once a mine (or a portion of it) is developed, the development sections may then become "retreat" mining sections. In retreat mining, coal pillars that were originally left in place for support of the mine entries and crosscuts are themselves extracted. The basic approach is to mine in a series of cuts, supporting the roof with timbers, bolts, or a combination of both. As these pillars are removed completely, the mine roof they once supported collapses.

In many large mines, retreat mining has been replaced by longwall mining. To establish a longwall, two parallel continuous miner sections, each consisting of two to four entries, are advanced 5,000 ft or more to a predetermined point. They are then turned and driven toward each other until they join. Once these sections are joined, they have created a large block of coal, 600 to 1,000 ft wide and approximately a mile long, that is known as a longwall "panel." Crews on a longwall mining section are made up of 8 to 10 individuals. A crew might consist of (1) one supervisor, (2) two shearer operators, (3) two shield operators, (4) one headgate operator, (5) one tailgate operator, and (6) one mechanic. These workers run large specialized equipment, which has been dismantled on the most recently mined longwall section, then brought in and set up at the new face. Panel extraction consists of completely removing this large block of coal that was created during the development process. Strata are allowed to cave behind the longwall as coal is mined back in the direction from which the parallel "setup" sections were started.

Longwall mining operations depend on the use of self-advancing hydraulic roof supports called "shields." These are massive overhead steel structures supported by large multistage hydraulic jacks. The jack system allows shields to be raised and lowered mechanically as a face is advanced. Shields are placed side-by-side in a row so that they form a protective canopy along the entire length of the working face. Coal is removed from the face by a rotary drum shearing machine or "shearer." This shearer rides on top of a flexible, segmented conveyor ("pan line") that runs along the face. It is attached to the front of the shields by hydraulic jacks. The shearer has circular cutting heads mounted on long arms that are affixed to each end of its main body frame. A cutting head is equipped with carbide bits arranged in a spiral formation. The head rotates to cut a strip of coal 30 to 40 inches deep from the longwall face as it is moved across the panel. This extracted coal falls onto the pan line for transportation across the face to the panel's belt conveyor. The panel conveyor then moves the coal to the mine's main haulage belt for transport outside.

Fresh air must be supplied to all working areas of a mine. Air is drawn into a mine from the outside by one or more propeller-type, axial-vane fans that may be as large as 8 ft in diameter. These fans can move several hundred thousand cubic feet of air per minute. Entries serve as "intake" (fresh) and "return" (contaminated) aircourses that channel the air through a mine. Intake and return aircourses are separated by concrete block walls ("stoppings") that are built in the crosscuts between entries. Where intake and return aircourses must cross each other, air bridges ("overcasts") are used. Air moving through the mine and sweeping across its working faces carries away smoke, dust, and accumulations of methane gas. The intake and return aircourses also function as escapeways for miners should a fire or other type of emergency occur. Federal mining law requires that underground mines must maintain two separate and distinct travelable passageways designated as escapeways from each working section. At least one of these two escapeways has to be located in fresh air.

While an underground coal mine is in some respects like a factory, the working environment is very different. The only lighting, for instance, comes from miners' battery-operated cap lamps or from localized sources on various equipment. At the face, production crews must contend with work areas that can be dusty, or wet and muddy depending on the amount of water that may be present. These places can also be extremely confined, especially in mines where the seam thickness is not great. To extract coal, miners must operate large machines under such conditions. Outby1 support personnel are scattered through the labyrinth of underground entries. They are needed to help maintain the many auxiliary subsystems found in the mine. Work done by these miners includes building and maintaining air stoppings, installing supplemental roof supports, cleaning coal spills around or under conveyor haulage belts, moving supplies, maintaining electrical installations, and conducting hazard inspections. Generally, these support workers do their tasks singly or in small crews, usually without direct contact with other miners, supervisors, or the outside world. They also have to deal with poor footing due to uneven or muddy bottom. In sum, all miners must do their jobs in an environment that is harsh and potentially dangerous.

APPENDIX E – GLOSSARY

A

Active workings - Any place in a mine where miners are normally required to work or travel and which are ventilated and inspected regularly.

Advance - Mining in the same direction, or order of sequence; first mining as distinguished from retreat.

Air split - The division of a current of air into two or more parts.

Airway - Any passage through which air is carried. Also known as an air course.

Angle of dip - The angle at which strata or mineral deposits are inclined to the horizontal plane.

Angle of draw - In coal mine subsidence, this angle is assumed to bisect the angle between the vertical and the angle of repose of the material and is 20□ for flat seams. For dipping seams, the angle of break increases, being 35.8□ from the vertical for a 40□ dip. The main break occurs over the seam at an angle from the vertical equal to half the dip.

Angle of repose - The maximum angle from horizontal at which a given material will rest on a given surface without sliding or rolling.

Anticline - An upward fold or arch of rock strata.

Aquifer - A water-bearing bed of porous rock, often sandstone.

Arching - Fracture processes around a mine opening, leading to stabilization by an arching effect.

Area (of an airway) - Average width multiplied by average height of airway, expressed in square feet.

Auger - A rotary drill that uses a screw device to penetrate, break, and then transport the drilled material (coal).

Auxiliary operations - All activities supportive of but not contributing directly to mining.

Auxiliary ventilation - Portion of main ventilating current directed to face of dead end entry by means of an auxiliary fan and tubing.

B

Back - The roof or upper part in any underground mining cavity.

Barricading - Enclosing part of a mine to prevent inflow of noxious gasses from a mine fire or an explosion.

Barrier - Something that bars or keeps out. Barrier pillars are solid blocks of coal left between two mines or sections of a mine to prevent accidents due to inrushes of water, gas, or from explosions or a mine fire.

Belt conveyor - A looped belt on which coal or other materials can be carried and which is generally constructed of flame-resistant material or of reinforced rubber or rubber-like substance.

Bench - One of to or more divisions of a coal seam separated by slate or formed by the process of cutting the coal.

Black damp - A term generally applied to carbon dioxide. Strictly speaking, it is a mixture of carbon dioxide and nitrogen. It is also applied to an atmosphere depleted of oxygen, rather than having an excess of carbon dioxide.

Bleeder or bleeder entries - Special air courses developed and maintained as part of the mine ventilation system and designed to continuously move air-methane mixtures emitted by the gob or at the active face away from the active workings and into mine-return air courses. Alt: Exhaust ventilation lateral.

Boss - Any member of the managerial ranks who is directly in charge of miners (e.g., "shift-boss," "face-boss," "fire-boss," etc.).

Brattice or brattice cloth - Fire-resistant fabric or plastic partition used in a mine passage to confine the air and force it into the working place. Also termed "line brattice," "line canvas," or "line curtain."

Breakthrough - A passage for ventilation that is cut through the pillars between rooms.

Brow - A low place in the roof of a mine, giving insufficient headroom.

Brushing - Digging up the bottom or taking down the top to give more headroom in roadways.

Btu – British thermal unit. A measure of the energy required to raise the temperature of one pound of water one degree Fahrenheit.

Bump (or burst) - A violent dislocation of the mine workings which is attributed to severe stresses in the rock surrounding the workings.

C

Cap - A miner's safety helmet. Also, a highly sensitive, encapsulated explosive that is used to detonate larger but less sensitive explosives.

Car - A railway wagon, especially any of the wagons adapted to carrying coal, ore, and waste underground.

Certified - Describes a person who has passed an examination to do a required job.

Check curtain - Sheet of brattice cloth hung across an airway to control the passage of the air current.

Coal - A solid, brittle, more or less distinctly stratified combustible carbonaceous rock, formed by partial to complete decomposition of vegetation; varies in color from dark brown to black; not fusible without decomposition and very insoluble.

Coal dust - Particles of coal that can pass a No. 20 sieve.

Coal mine - An area of land and all structures, facilities, machinery, tools, equipment, shafts, slopes, tunnels, excavations, and other property, real or personal, placed upon, under, or above the surface of such land by any person, used in extracting coal from its natural deposits in the earth by any means or method, and the work of preparing the coal so extracted, including coal preparation facilities. British term is "colliery".

Conveyor - An apparatus for moving material from one point to another in a continuous fashion. This is accomplished with an endless (that is, looped) procession of hooks, buckets, wide rubber belt, etc.

Cover - The overburden of any deposit.

Crib - A roof support of prop timbers or ties, laid in alternate cross-layers, log-cabin style. It may or may not be filled with debris. Also may be called a chock or cog.

Crosscut - A passageway driven between the entry and its parallel air course or air courses for ventilation purposes. Also, a tunnel driven from one seam to another through or across the intervening measures; sometimes called "crosscut tunnel", or "breakthrough". In vein mining, an entry perpendicular to the vein.

Cross entry - An entry running at an angle with the main entry.

D

Detectors - Specialized chemical or electronic instruments used to detect mine gases.

Development mining - Work undertaken to open up coal reserves as distinguished from the work of actual coal extraction.

Diffusion - Blending of a gas and air, resulting in a homogeneous mixture. Blending of two or more gases.

Dilute - To lower the concentration of a mixture; in this case the concentration of any hazardous gas in mine air by addition of fresh intake air.

Dip - The inclination of a geologic structure (bed, vein, fault, etc.) from the horizontal; dip is always measured downwards at right angles to the strike.

Drift - A horizontal passage underground. A drift follows the vein, as distinguished from a crosscut that intersects it, or a level or gallery, which may do either.

Drift mine – An underground coal mine in which the entry or access is above water level and generally on the slope of a hill, driven horizontally into a coal seam.

Dynamic pressure – The pressure increase that moving fluid imparts upon an object in its path and is expressed as a velocity of the object.

E

Entry - An underground horizontal or near-horizontal passage used for haulage, ventilation, or as a mainway; a coal heading; a working place where the coal is extracted from the seam in the initial mining; same as "gate" and "roadway," both British terms.

F

Face – The exposed area of a coal bed from which coal is being extracted.

Face conveyor - Any conveyor used parallel to a working face which delivers coal into another conveyor or into a car.

Fall - A mass of roof rock or coal which has fallen in any part of a mine.

Feeder - A machine that feeds coal onto a conveyor belt evenly.

Fire damp - The combustible gas, methane, CH_4. Also, the explosive methane-air mixtures with between 5% and 15% methane. A combustible gas formed in mines by decomposition of coal or other carbonaceous matter, and that consists chiefly of methane.

Float dust - Fine coal-dust particles carried in suspension by air currents and eventually deposited in return entries. Dust consisting of particles of coal that can pass through a No. 200 sieve.

Floor - That part of any underground working upon which a person walks or upon which haulage equipment travels; simply the bottom or underlying surface of an underground excavation.

Fly ash – The finely divided particles of ash suspended in gases resulting from the combustion of fuel. Electrostatic precipitators are used to remove fly ash from the gases prior to the release from a power plant's smokestack.

Formation – Any assemblage of rocks which have some character in common, whether of origin, age, or composition. Often, the word is loosely used to indicate anything that has been formed or brought into its present shape.

Friable - Easy to break, or crumbling naturally. Descriptive of certain rocks and minerals.

G

Gathering conveyor; gathering belt - Any conveyor which is used to gather coal from other conveyors and deliver it either into mine cars or onto another conveyor. The term is frequently used with belt conveyors placed in entries where a number of room conveyors deliver coal onto the belt.

Gob - The term applied to that part of the mine from which the coal has been removed and the space more or less filled up with waste. Also, the loose waste in a mine. Also called goaf.

Ground pressure - The pressure to which a rock formation is subjected by the weight of the superimposed rock and rock material or by diastrophic forces created by movements in the rocks forming the earth's crust. Such pressures may be great enough to cause rocks having a low compressional strength to deform and be squeezed into and close a borehole or other underground opening not adequately strengthened by an artificial support, such as casing or timber.

Gunite - A cement applied by spraying to the roof and sides of a mine passage.

H

Haulage - The horizontal transport of ore, coal, supplies, and waste. The vertical transport of the same is called hoisting.

Haulageway - Any underground entry or passageway that is designed for transport of mined material, personnel, or equipment, usually by the installation of track or belt conveyor.

Head section - A term used in both belt and chain conveyor work to designate that portion of the conveyor used for discharging material.

Heaving - Applied to the rising of the bottom after removal of the coal; a sharp rise in the floor is called a "hogsback".

Hogsback - A sharp rise in the floor of a seam.

Horseback - A mass of material with a slippery surface in the roof; shaped like a horse's back.

I

Inby - In the direction of the working face.

Incline - Any entry to a mine that is not vertical (shaft) or horizontal (adit). Often incline is reserved for those entries that are too steep for a belt conveyor (+17 degrees -18 degrees), in which case a hoist and guide rails are employed. A belt conveyor incline is termed a slope. Alt: Secondary inclined opening, driven upward to connect levels, sometimes on the dip of a deposit; also called "inclined shaft".

Intake - The passage through which fresh air is drawn or forced into a mine or to a section of a mine.

J

Job Safety Analysis (J.S.A.) - A job breakdown that gives a safe, efficient job procedure.

K

Kettle bottom - A smooth, rounded piece of rock, cylindrical in shape, which may drop out of the roof of a mine without warning. The origin of this feature is thought to be the remains of the stump of a tree that has been replaced by sediments so that the original form has been rather well preserved.

L

Lamp - The electric cap lamp worn for visibility. Also, the flame safety lamp used in coal mines to detect methane gas concentrations and oxygen deficiency.

Layout - The design or pattern of the main roadways and workings. The proper layout of mine workings is the responsibility of the manager aided by the planning department.

Longwall Mining – One of three major underground coal mining methods currently in use. Employs a steal plow, or rotation drum, which is pulled mechanically back and forth across a face of coal that is usually several hundred feet long. The loosened coal falls onto a conveyor for removal from the mine.

Loose coal - Coal fragments larger in size than coal dust.

Low voltage - Up to and including 660 volts by federal standards.

M

Main entry - A main haulage road. Where the coal has cleats, main entries are driven at right angles to the face cleats.

Manhole - A safety hole constructed in the side of a gangway, tunnel, or slope in which miner can be safe from passing locomotives and car. Also called a refuge hole.

Man trip - A carrier of mine personnel, by rail or rubber tire, to and from the work area.

Manway - An entry used exclusively for personnel to travel form the shaft bottom or drift mouth to the working section; it is always on the intake air side in gassy mines. Also, a small passage at one side or both sides of a breast, used as a traveling way for the miner, and sometimes, as an airway, or chute, or both.

Methane – A potentially explosive gas formed naturally from the decay of vegetative matter, similar to that which formed coal. Methane, which is the principal component of natural gas, is frequently encountered in underground coal mining operations and is kept within safe limits through the use of extensive mine ventilation systems.

Methane monitor - An electronic instrument often mounted on a piece of mining equipment, that detects and measures the methane content of mine air.

Mine development - The term employed to designate the operations involved in preparing a mine for ore extraction. These operations include tunneling, sinking, cross-cutting, drifting, and raising.

Miner - One who is engaged in the business or occupation of extracting ore, coal, precious substances, or other natural materials from the earth's crust.

MSHA - Mine Safety and Health Administration; the federal agency which regulates coal mine health and safety.

N

Natural ventilation - Ventilation of a mine without the aid of fans or furnaces.

O

Outby; outbye - Nearer to the shaft, and hence farther from the working face. Toward the mine entrance. The opposite of inby.

Overburden – Layers of soil and rock covering a coal seam. Overburden is removed prior to surface mining and replaced after the coal is taken from the seam.

P

Panel - A coal mining block that generally comprises one operating unit.

Parting - (1) A small joint in coal or rock; (2) a layer of rock in a coal seam; (3) a side track or turnout in a haulage road.

Peak overpressure – The maximum pressure above atmospheric pressure reached in rapidly advancing blast wave.

Permissible - That which is allowable or permitted. It is most widely applied to mine equipment and explosives of all kinds which are similar in all respects to samples that have passed certain tests of the MSHA and can be used with safety in accordance with specified conditions where hazards from explosive gas or coal dust exist.

Permit – As it pertains to mining, a document issued by a regulatory agency that gives approval for mining operations to take place.

Pillar - An area of coal left to support the overlying strata in a mine; sometimes left permanently to support surface structures.

Pinch - A compression of the walls of a vein or the roof and floor of a coal seam so as to "squeeze" out the coal.

Pinning - Roof bolting.

Pitch - The inclination of a seam; the rise of a seam.

Plan - A map showing features such as mine workings or geological structures on a horizontal plane.

Portal - The structure surrounding the immediate entrance to a mine; the mouth of an adit or tunnel.

Portal bus - Track-mounted, self-propelled personnel carrier that holds 8 or more.

Post - The vertical member of a timber set.

R

Raise - A secondary or tertiary inclined opening, vertical or near-vertical opening driven upward form a level to connect with the level above, or to explore the ground for a limited distance above one level.

Ramp - A secondary or tertiary inclined opening, driven to connect levels, usually driven in a downward direction, and used for haulage.

Resin bolting - A method of permanent roof support in which steel rods are grouted with resin.

Respirable dust - Dust particles 5 microns or less in size.

Retreat mining - A system of robbing pillars in which the robbing line, or line through the faces of the pillars being extracted, retreats from the boundary toward the shaft or mine mouth.

Return - The air or ventilation that has passed through all the working faces of a split.

Rib - The side of a pillar or the wall of an entry. The solid coal on the side of any underground passage. Same as rib pillar.

Roll - (1) A high place in the bottom or a low place in the top of a mine passage, (2) a local thickening of roof or floor strata, causing thinning of a coal seam.

Roof - The stratum of rock or other material above a coal seam; the overhead surface of a coal working place. Same as "back" or "top."

Roof bolt - A long steel bolt driven into the roof of underground excavations to support the roof, preventing and limiting the extent of roof falls. The unit consists of the bolt (up to 4 feet long), steel plate, expansion shell, and pal nut. The use of roof bolts eliminates the need for timbering by fastening together, or "laminating," several weaker layers of roof strata to build a "beam."

Roof fall - A coal mine cave-in especially in permanent areas such as entries.

Roof sag - The sinking, bending, or curving of the roof, especially in the middle, from weight or pressure.

Roof stress - Unbalanced internal forces in the roof or sides, created when coal is extracted.

Room and pillar mining – A method of underground mining in which approximately half of the coal is left in place to support the roof of the active mining area. Large "pillars" are left while "rooms" of coal are extracted.

Room neck - The short passage from the entry into a room.

S

Scaling - Removal of loose rock from the roof or walls. This work is dangerous and a long bar (called a scaling bar)is often used.

Scoop - A rubber tired-, battery- or diesel-powered piece of equipment designed for cleaning runways and hauling supplies.

Scrubber – Any of several forms of chemical/physical devices that remove sulfur compounds formed during coal combustion. These devices, technically know as flue gas desulfurization systems, combine the sulfur in gaseous emissions with another chemical medium to form inert "sludge," which must then be removed for disposal.

Seal – An approved structure installed or constructed across openings leading to abandoned or worked out areas that separate the active ventilated areas of the mine. The goal of sealing an area is to create an inert, oxygen deficient atmosphere that prohibits the propagation of an explosion or fire thus protecting the active, ventilated areas underground.

Seam - A stratum or bed of coal.

Section - A portion of the working area of a mine.

Self-contained self-rescuer (SCSR) – A device that either stores oxygen in cylinder or chemical generates oxygen, to aid and protect a miner in escape of a mine in the event of an explosion or fire.

Shaft - A primary vertical or non-vertical opening through mine strata used for ventilation or drainage and/or for hoisting of personnel or materials; connects the surface with underground workings.

Shift - The number of hours or the part of any day worked.

Shuttle car – A self-discharging truck, generally with rubber tires or caterpillar-type treads, used for receiving coal from the loading or mining machine and transferring it to an underground loading point, mine railway or belt conveyor system.

Skid - A track-mounted vehicle used to hold trips or cars from running out of control. Also it is a flat-bottom personnel or equipment carrier used in low coal.

Skip - A car being hoisted from a slope or shaft.

Slate - A miner's term for any shale or slate accompanying coal. Geologically, it is a dense, fine-textured, metamorphic rock, which has excellent parallel cleavage so that it breaks into thin plates or pencil-like shapes.

Slip - A fault. A smooth joint or crack where the strata have moved on each other.

Slope - Primary inclined opening, connection the surface with the underground workings.

Slope mine – An underground mine with an opening that slopes upward or downward to the coal seam.

Sloughing - The slow crumbling and falling away of material from roof, rib, and face.

Solid - Mineral that has not been undermined, sheared out, or otherwise prepared for blasting.

Sounding - Knocking on a roof to see whether it is sound and safe to work under.

Span - The horizontal distance between the side supports or solid abutments along sides of a roadway.

Split - Any division or branch of the ventilating current. Also, the workings ventilated by one branch. Also, to divide a pillar by driving one or more roads through it.

Squeeze - The settling, without breaking, of the roof and the gradual upheaval of the floor of a mine due to the weight of the overlying strata.

Static pressure – The force per unit area exerted across a surface parallel to the direction of the flow.

Steeply inclined - Said of deposits and coal seams with a dip of from 0.7 to 1 rad (40 degrees to 60 degrees).

Support - The all-important function of keeping the mine workings open. As a verb, it refers to this function; as a noun it refers to all the equipment and materials--timber, roof bolts, concrete, steel, etc.--that are used to carry out this function.

T

Tagline - A section of rope provided to allow escaping miners to stay together during an escape in smoke filled environment.

Tailgate - A subsidiary gate road to a conveyor face as opposed to a main gate. The tailgate commonly acts as the return airway and supplies road to the face.

Tailpiece - Also known as foot section pulley. The pulley or roller in the tail or foot section of a belt conveyor around which the belt runs.

Tail section - A term used in both belt and chain conveyor work to designate that portion of the conveyor at the extreme opposite end from the delivery point. In either type of conveyor it consists of a frame and either a sprocket or a drum on which the chain or belt travels, plus such other devices as may be required for adjusting belt or chain tension.

Top - A mine roof; same as "back."

Tractor - A battery-operated or diesel piece of equipment that pulls trailers, skids, or personnel carriers. Also used for supplies.

Tram - Used in connection with moving self-propelled mining equipment. A tramming motor may refer to an electric locomotive used for hauling loaded trips or it may refer to the motor in a cutting machine that supplies the power for moving or tramming the machine.

Tunnel - A horizontal, or near-horizontal, underground passage, entry, or haulageway, that is open to the surface at both ends. A tunnel (as opposed to an adit) must pass completely through a hill or mountain.

U

Underground mine – Also known as a "deep" mine. Usually located several hundred feet below the earth's surface, an underground mine's coal is removed mechanically and transferred by shuttle car or conveyor to the surface.

Underground station - An enlargement of an entry, drift, or level at a shaft at which cages stop to receive and discharge cars, personnel, and material. An underground station is any location where stationary electrical equipment is installed. This includes pump rooms, compressor rooms, hoist rooms, battery-charging rooms, etc.

Upcast shaft - A shaft through which air leaves the mine.

V

Velocity - Rate of airflow in lineal feet per minute.

Ventilation - The provision of a directed flow of fresh and return air along all underground roadways, traveling roads, workings, and service parts.

Violation - The breaking of any state or federal mining law.

W

White damp - Carbon monoxide, CO. A gas that may be present in the afterdamp of a gas- or coal-dust explosion, or in the gases given off by a mine fire; also one of the constituents of the gases produced by blasting. Rarely found in mines under other circumstances. It is absorbed by the hemoglobin of the blood to the exclusion of oxygen. One-tenth of 1% (.001) may be fatal in 10 minutes.

Working face - Any place in a mine where material is extracted during a mining cycle.

Working place - From the outby side of the last open crosscut to the face.

Workings - The entire system of openings in a mine for the purpose of exploitation.

Working section - From the faces to the point where coal is loaded onto belts or rail cars to begin its trip to the outside.

WEST VIRGINIA BOARD OF COAL MINE HEALTH AND SAFETY

1615 Washington Street East • Charleston, West Virginia 25311-2126 • Telephone304-558-1425 • Fax 304-558-6091

May 30, 2006

Jim Dean, Acting Director
WV Office of Miners Health, Safety & Training
1615 Washington Street East
Charleston, WV 25311

Dear Director Dean:

We the members of the WV Board of Coal Mine Health and Safety have reviewed the WV Mine Safety Technology Task Force report, dated May 25, 2006. We wholeheartedly support and endorse the recommendations within the report.

Additionally, the Board would like to compliment each individual member for his dedication and hard work as it relates to the health and safety of West Virginia coal miners.

The board would also like to commend the Task Force for the depth and the breadth of the report.

It has been our pleasure to work with the task force members as well as with the Office of Miners Health Safety and Training and we look forward to providing the necessary joint assistance and support in carrying out the recommendations outline in the report.

Dave Ashby

Charles "Chuck" Boggs

Steve Cook

Carl Egnor

Rick Glover

Chris Hamilton

cc: Governor Joe Manchin, III
Carte Goodwin
Senate President Earl Ray Tomblin
House Speaker Robert Kiss
Senator Don Caruth
Senator Jeff Kessler
Senator Shirley Love
Delegate Eustace Frederick
Delegate Mike Caputo
Delegate Bill Hamilton
Task Force Members

3. Refuge Location Analysis

3.1 Introduction

In the analysis conducted in Phase I of this project, we reviewed a total of forty two (42) past mining disasters and studied the impact refuge stations[1] would have had on the final outcomes of thirty eight (38) of those disasters most applicable to the project. All disasters occurred between 1970 and 2006 and involved fires, explosions, and inundations in which at least one fatality occurred. MSHA reports were reviewed and data collected on the type of incident, number of survivors, and the number and type of fatalities. The potential effect of refuge chambers on both survivors and fatalities was estimated. The amount of data is limited; we provided the best analysis possible within the confines of the information available.

The objective of the ongoing analyses of past mining disasters in Phase II of the project has been to build on the earlier studies to reach final conclusions and recommendations on the placement of stations within underground coal mines to help save miners lives in the event of future disasters. To do this, we engaged in a two-pronged approach:

1. We conducted an additional review of all 42 disasters studied in Phase I to determine if the point of origin of the disaster (fire, explosion, etc.) occurred at a working face or some distance away and how this might correlate with the outcome on miners lives and therefore on the placement of stations.

2. We selected a subset of those disasters studied in Phase I that were most relevant for the potential of stations to save miners lives and studied them in greater depth to more accurately pinpoint how stations might have been used in those cases.

Based on these studies, we were able to reach final conclusions and provide a series of recommendations for the use of stations in coal mines. The following subsections present the results of our Phase II studies and our recommendations for the use of refuge stations. A bibliography listing the resources we used to conduct the analyses on this project is provided in Appendix B. The bibliography also includes contact information for those individuals that either met with us regarding the project or provided us with some of the materials used in the analyses.

3.2 A Study of the Locations of Mine Disasters Within the Mines

An additional review was conducted of all of the forty two (42) disasters studied in Phase I to determine if the point of origin of the disaster occurred at a working face or some distance away. This was expected to shed light on how the point of origin of a disaster might correlate with the outcome on miner's lives. In the case of explosions, for example, it was assumed that an explosion right at the working face would instantly

[1] Throughout this document the term *station* refers to either portable refuge chambers or to bulkhead-based refuge locations.

either kill or severely injure the miners in the area, limiting the potential ability of a refuge station to have a positive impact. Explosions elsewhere in the mine, on the other hand, would be expected to have a less dramatic impact on most of the affected miners.

In the case of mine fires or gas inundations, the reverse could be true. A fire or gas inundation near the working face would likely be discovered quickly and miners on the working section would probably be able to readily escape through an intake escapeway. Fires or inundations in outby areas, on the other hand, might not be discovered and communicated to inby miners in a timely manner and could contaminate intake airways or belt entries leading into working sections.

Table 1, Table 2, and Table 3 below present the basic data from this review. Because of their differing impact on disaster outcomes, explosions and fires/inundations are tabulated separately. For completeness, a third table lists remaining disasters of the total 42 originally studied that are not applicable to this review.

Table 1. Mine Explosions

	MINE	EXPLOSION AT FACE AREA?
1	Darby Mine Explosion	No – 1000 ft away; 2 victims near explosion died instantly; 3 in face died later
2	Sago Mine Explosion	No – 2300 ft outby; 1 victim near explosion died instantly; 11 in face died later
3	Pyro No. 9, William Station Explosion (1989)	No – 450 ft inby; 4 victims along longwall face closest to explosion died instantly; 6 further from explosion died later
4a	Scotia Mine Explosion – 1st explosion	No – 800 ft inby; 6 of 15 victims killed instantly; of 9 others near face, 3 likely survived a short time and 6 others died in barricade
4b	Scotia Mine Explosion – 2nd explosion	No – 2500 ft inby; all 11 victims located in an outby area died instantly
5	Oakwood Red Ash Explosion	No – 6000 ft away; 2 victims near explosion were not killed instantly
6	Itmann No. 3 Mine Explosion	No – 1000 ft outby; of 8 miners near explosion, 5 were killed (instantly or nearly so) and 3 were injured
7	Blacksville No. 1 Fire & Explosion (1972)*	No – occurred between mine fire and face area (report is not specific on location); no deaths were related to this explosion
8	Finley 15 & 16 Mine Explosion	No – 150 to 1500 ft away; 33 of 38 affected miners were killed instantly
9	Pyro No. 2 Mine Explosion	No – 1 of 2 men surveying old works died; the other escaped; explosion occurred a considerable distance from active areas (data not provided); no other miners affected
10	Jim Walters Resources, Inc., No. 5 Mine	No - 2 explosions: one (minor) about 400 ft outby the faces; the other (major) about 1,000 ft outby the faces; the major explosion killed 12 of 13 victims instantly, none near faces at the time

	MINE	EXPLOSION AT FACE AREA?
11	Southmountain Coal Co., Inc. - #3 Mine	Yes (or very close); 8 of 9 victims killed instantly
12	McClure #1 Mine	Yes (or very close); 3 of 7 victims killed instantly; others too injured to escape
13	RFH Coal Co., #1 Mine	Yes; 2 of 7 victims killed instantly; others too injured to escape
14	Grundy Mining Co., #21 Mine	Yes (or very close); all 13 victims killed instantly
15	Adkins Mining Company, No. 11 Mine	Yes; all 8 victims killed instantly
16	Mid-Continent, Dutch Creek #1 Mine	Yes; all 15 victims killed instantly
17	Westmoreland Coal Co., Ferrell No. 17 Mine	No – distance from active faces unknown; 5 miners retrieving track in an abandoned area and all 5 victims killed instantly
18	R&D Coal Company, Inc. Mine	Yes; all 1 victim killed instantly
19	Plateau Mining Corp., Willow Creek Mine	Yes; all 2 victims killed instantly
20	A.A. & W Coals Inc. Elmo #5 Mine	No – one miner alone in old works died instantly or very soon after igniting methane; explosion was about 2,000 ft inby active section; only one miner on the active section was injured
21	Fire Creek Inc. #1 Mine	Yes (but no active mining in progress); all 2 victims killed instantly
22	Granny Rose Coal Company, No. 3 Mine	Yes; all 3 victims killed instantly
23	Double R Coal Co., #1Mine	Yes (or very close; victim alone in mine)
24	Mid Continent Inc., Dutch Creek #2 Mine	Yes; none killed instantly; all escaped and one died in hospital
25	Pyro No. 9, William Station Explosion (1986)	Yes; none killed instantly but 2 of 3 injured; one died one week later
26	M.S.W. Coal Company, No. 2 Slope Mine	Yes; 5 miners in area: 3 died; 2 killed instantly
27	Greenwich Collieries No. 1 Mine	Yes; all 3 victims killed instantly
28	Helen Mining Co., Homer City Mine (1983)	No – explosion occurred in a section inactive due to mine vacation; distance to faces unknown (without access to mine maps); victim alone conducting fire patrol ignited methane
29	P and P Coal Company, No. 2 Mine	No – all 4 miners retrieving equipment from old works died instantly; explosion occurred a considerable distance from active areas (data not provided); 16 miners in other areas escaped
30	Helen Mining Co., Homer City Mine (1970)	Yes; 5 miners in area: 3 injured and 1 killed
31	Clinchfield Coal Co., Compass #2 Mine	No – one miner died while traveling alone when his personnel carrier ignited methane; distance to active areas unknown (without access to mine maps); mine was idle at the time

* Note that this explosion occurred some time after a mine fire had developed. This disaster is also shown in the table below related to mine fires.

Table 2. Mine Fires/Inundations

	MINE	FIRE/INUNDATION AT FACE AREA?
32	Emery Mining Corp - Wilberg Mine Fire	No (about 2,200 ft outby longwall face); 27 victims of 28 miners in face area
33	Blacksville No. 1 Fire & Explosion (1972)**	No (1,900 ft and 3,500 ft outby two longwall working sections); 9 of 9 victims
34	Aracoma Coal Co., Inc, Alma Mine #1 Fire	No (about 3,500 outby working section); 2 victims of 12 miners escaping face area
35	Buckeye Coal Co., Nemacolin Mine Fire	Yes (3 crosscuts - about 300 ft outby faces); 9 of 10 miners in section escaped and 1 died; 2nd victim was found about 1,100 ft outby
36	Grays Knob Coal Company, No. 5 Mine	Yes (inundation of CO_2; 3 miners in face area died; others escaped)

** Note that this fire included an explosion that occurred some time after the fire had developed. This disaster is also shown in the table above related to mine explosions.

Table 3. Disasters Not Applicable to This Study

	MINE (not applicable to this study)	NATURE OF DISASTER
37	Black Wolf Coal Co., Quecreek #1 Mine	Inundation of water; no deaths; all 9 miners impacted were rescued
38	Consolidation Coal Co., Loveridge #22 mine	Suffocation in coal storage bin
39	Clinchfield Coal Co., Moss #3 Portal A Mine	CO_2 inundation 265 ft from surface of mine
40	Kocher Coal Corporation, Porter Tunnel Mine	Water inundation in multi-level anthracite mine
41	Jim Walters Resources, No. 4 Mine	CO asphyxiation in an outby area
42	R and R Coal Company, No 3 Mine	CO asphyxiation near mine surface following a production blast with explosives
43	Consolidation Coal Co., Blacksville #1 Mine (1992)	Above-ground explosion at production shaft

3.2.1 Analysis and Conclusions

For the 32 mine explosions reviewed (including two separate explosions at Scotia), 16 occurred at a working face area while the other 16 occurred some distance away from a face area or elsewhere in the mine. Of the 16 explosions occurring at the working face, all of the miners who perished were killed instantly in eight of them. In four others, some of the miners were killed instantly and others died some time later. In two other explosions, one miner in each explosion died in the mine but the time of death is unknown. In the remaining two explosions, one miner in each explosion died after being removed from the mine.

Of the 16 explosions *not* occurring at a working face, only six directly affected miners were working in face areas at the time of the explosion. Of these six explosions, three resulted in the deaths of face area miners but none were killed instantly; all were killed later while attempting to escape or awaiting rescue. In another two explosions, some or most of the face area miners *were* killed instantly due to the violence of the explosion. In one of the explosions, a face area worker was injured but not killed.

Of the remaining ten of the 16 explosions *not* occurring at a working face, seven events affected only the miners who were in the vicinity of the explosion. Miners in face areas were not affected. In all of these cases except one, all of the miners in the immediate vicinity of the explosion were either killed or injured. In only one case, a miner in the immediate vicinity of the explosion was able to escape uninjured. In two additional explosions (the second explosion at Scotia and the explosion at Jim Walter No. 5 Mine), miners some distance outby the point of origin of the explosion were killed (and most of them instantly) by the violence of the explosion. One explosion (Blacksville No. 1 Mine) was minor and had no effect on any of the miners.

Of the 4 mine fires that were reviewed, three originated a considerable distance from face areas. In the Wilberg fire, 27 of the 28 miners present in the longwall face area perished trying to escape the smoke and gasses from the outby fire. In the Blacksville fire, all 9 of the miners in two face areas perished trying to escape the smoke and gasses from the outby fire. In the Alma fire, 2 of 12 miners escaping the fire became separated from the rest of the group and perished. In the Nemacolin Mine fire, which did occur near the working faces, one of 10 miners escaping the fire left the group and perished while another miner attempting to escape separately was not successful.

One gas inundation was represented in the study, occurring right at the active face area. In the Grays Knob CO_2 inundation, all but three of the crewmembers were able to escape while three perished.

Generally, the above conclusions supported our expectations. Explosions occurring right at working faces killed all or some of the affected section miners instantly in most cases, while face area miners were *not* killed instantly in most cases of explosions occurring away from the face. In cases of particularly violent outby explosions (Scotia, Jim Walters and Finley, for example), face area miners still died instantly from the explosions.

In the case of the four fires studied, one of them (Nemacolin) originated close to the working faces, was discovered immediately by section personnel and most of the miners were able to escape quickly. The other three fires occurred well away from face areas and two of them resulted in significant loss of life because they were not communicated to face areas in a timely manner and escape routes were blocked.

The results of this study show that in nearly all cases, it is disasters that occur away from the face areas that provide the best opportunity for underground refuge stations to have an impact in saving miners lives. Unfortunately, face area explosions with sufficient forces to kill miners will kill most of them instantly, rendering stations irrelevant in most cases. Explosions away from face areas on the other hand allow surviving miners an opportunity to attempt escape or to seek refuge in stations if escape is not possible.

Stations are also very viable in saving miners lives in the cases of fires originating away from face areas where smoke, gasses and heat block the miners escape routes.

3.3 Detailed Analyses of Selected Mining Disasters

During our review in Phase I of the 38 applicable past disasters, we assessed whether a refuge station would have had a "positive", a "neutral" or a "negative" impact on the miners affected by the disaster if a refuge station had been present in the mine at the time. We did this for two basic situations:

1. Situations in which the miners escaped successfully, did not escape but were rescued or barricaded and were rescued.

2. Situations in which the miners died attempting to escape, barricaded and perished, or were too injured to escape and were either rescued or perished.

Clearly the most important impact that refuge stations might have had on the outcomes of the disasters are those situations in which the stations might have saved miners lives, i.e., in which they would have had a "positive" impact on miners who died (Situation 2 above). There were twelve (12) such mine disasters in our original study and a key part of our Phase II effort has been to re-evaluate those twelve disasters in greater detail. It is notable that all but one of these 12 disasters originated well away from face areas, hence correlating well with the conclusions reached in the study of disaster locations discussed in the previous subsection.

The objective of this more extensive study of the 12 select disasters was to determine as accurately as possible, based on the specific situations of each disaster, where the affected miners were located when they died and what environmental or physical conditions to which they might have been subjected. The intent was to help determine where a refuge station might have best been located to provide the greatest chance of saving the miners lives and, to the extent possible based on the information available, the conditions that a station would have had to endure (i.e. fire, explosion forces, etc.).

The twelve mine disasters selected for further study were (in reverse chronological order):

1. Darby No. 1 Mine Explosion – May 20, 2006
2. Aracoma Alma No. 1 Mine Fire – January 19, 2006
3. Sago Mine Explosion – January 2, 2006
4. Pyro William Station Mine Explosion – September 13, 1989
5. Wilberg Mine Fire – December 19, 1984
6. Scotia Mine Explosion – March 9 and 11, 1976
7. Oakwood Red Ash No. 4 Mine Explosion – September 25, 1973
8. Itmann No. 3 Mine Explosion – December 16, 1972
9. Blacksville No. 1 Mine Fire – July 22, 1972

10. Nemacolin Mine Fire – March 26, 1971
11. Finley No. 15 and 16 Mine Coal Dust Explosions – December 30, 1970
12. Pyro No. 2 Mine Explosion – November 30, 1970

For each of these disasters, we attempted to answer a series of key questions:

- Where were the victims found within the mine? Were they at active working faces, at outby (or inby) areas during an escape from active faces or elsewhere in the mine (at work areas away from active faces, while traveling within the mine, etc.)?

- Where were the miners found with respect to the source of the explosion or fire?

- Where did the source of the explosion or fire occur with respect to working faces?

- If a station had been in place in the mine within 1,000 ft from the face (i.e. per West Virginia regulations [1]), would the affected miners have been able to reach it?

- If a station had been in place in the mine 2,000 ft from the face (i.e. coincident with MSHA's breathable air guidelines [2]), would the affected miners have been able to reach it?

- Would a station at 1,000 ft from the face have been a preferred location compared to a station at 2,000 ft from the face or vice versa?

- Would a station positioned at some location *other* than 1,000 ft or 2,000 ft from the face have been preferred?

- Would flame and/or explosion forces have impacted a station (at 1,000 ft from the face, 2,000 ft from the face or some other location if applicable)? To what range of explosive forces would a station at each location have been subjected (if such information is available)?

- How long would it have taken mine rescue personnel to reach the affected miners if they were located in a station at 1,000 ft from the face? At 2,000 ft from the face?

- Would additional outby stations beyond those relative to the face (i.e. at 1-hour travel distances, etc.) have been potentially applicable to the miners?

We focused the above questions on the locations of 1,000 ft from the face and 2,000 ft from the face (WV regulations and MSHA breathable air guidelines) because those criteria already exist and mines are already beginning to adhere to them. Unless there was a compelling reason to choose a station location different than 1,000 ft from the face or 2,000 ft from the face, we preferred to hold the study to a comparison between those two potential locations. In fact, the results of the twelve detailed studies showed that there was *not* a strong reason in any of the cases to choose an alternative station location.

Table 4 presents a summary of the results of the detailed study of the twelve select disasters and an assessment of the results and conclusions follows the table. Appendix A provides additional detail related to each of the twelve disasters including a mine map showing the location of the disaster within the mine, locations of the miners who perished, locations where refuge stations would have been positioned at 1,000 ft from the face or 2,000 ft from the face, etc.

Table 4. Summary of Detailed Analyses of Twelve Select Mine Disasters from 1970 to Present

		Darby Explosion May 20, 2006	Alma Mine Fire Jan 19, 2006	Sago Explosion Jan 2, 2006	Pyro Wm Station Explosion Sept 13, 1989	Wilberg Mine Fire Dec 19, 1984	Scotia Mine Explosion Mar 9-11, 1976	Oakwood Red Ash Explosion Sept 25, 1973	Itmann No. 3 Mine Explosion Dec 16, 1972	Blacksville No. 1 Fire & Explosion July 22, 1972	Nemacolin Mine Fire Mar 26, 1971	Finley 15 & 16 Mine Explosion Dec 30, 1970	Pyro No. 2 Mine Explosion Nov 30, 1970
1	Where were victims found with respect to working face?	3 at faces	At face	11 at face	4 at face	Various (to 1900' outby)	Mar 9: 13 at face	N/A	1000' outby	600-3000' outby	1 @ face; 1 outby	Various (most @ faces)	N/A
2	Were some victims in outby areas?	2 outby (at explosion)	No	1 outby (at explosion)	6 at 250' outby	Yes	Mar 11: 11 outby	2 in old works	Yes, on mantrip	Yes, escaping	1 @ 1100' outby	Yes	2 in old works
3	Where were victims found with respect to disaster point of origin?	3 at 1000'	3500' outby	2300' inby	450-1000' outby (?)	Nearby or inby	800' outby 2500' outby	At origin	At origin	500-1200' inby fire	1 inby; 1 outby	150-1500' away	At origin
4	Where did the event occur relative to face (or work area)?	1000' away	3500 ft outby	2300' outby	450' inby	2200 ft outby	800' inby; 2500' inby	6000' away	1000' outby	Inby fire; outby face	300 ft outby	150-1500' away	Away from face
5	Would victims have been able to reach a station 1,000 ft away?	Yes	Yes	Yes	Yes (?)	Yes	Yes (some)	Maybe, if present	Maybe, if nearby	Yes (A2&A3)	Yes	Unknown	Yes, if present but would not have used
6	Would victims have been able to reach a station 2,000 ft away?	Yes	Yes	Maybe	Maybe (?)	Yes	Yes (some)	Maybe, if present	No	No-A2 Yes-A3	Yes	N/A	
7	Which station location (1,000 ft or 2,000 ft away) would have been favored?	2,000 ft	Neither	1,000 ft	1,000 ft	1,000 ft	Cannot say	Cannot say	1,000 ft (by luck)	1000 ft-A2 2000 ft-A3	Neither	N/A	N/A
8	Would a station at a location other than 1,000 ft or 2,000 ft away have been better?	No	No	No	No	No	Yes (in section)	N/A	No	No	No	No	N/A
9	Would FLAME have affected a station at 1,000 ft away?	No	No	No	No	No	Yes	Yes, if present	Yes	Yes-A2 No-A3	No	Yes	No, if present
10	Would FLAME have affected a station at 2,000 ft away?	No	No	No	No	No (flame) Yes (heat)	No	No, if present	No	Yes-A2 Yes-A3	No	N/A	No, if present
11	Would FLAME have affected a station per OTHER guidelines?	N/A	N/A	N/A	N/A	N/A	Yes	N/A	N/A	N/A	N/A	N/A	N/A
12	Would FORCES have affected a station per at 1,000 ft away?	Yes; 15-20 psi	N/A (fire)	Yes; 2-5 psi	No	N/A (fire)	Yes	Yes	Yes; 2-4 psi	Yes (low)	N/A (fire)	Yes	No, if present
13	Would FORCES have affected a station at 2,000 ft away?	Yes; 2-4 psi	N/A (fire)	Yes; 2-5 psi	No	N/A (fire)	Yes	Yes	Yes; <2 psi	Yes (both)	N/A (fire)	N/A	No, if present
14	Would FORCES have affected a station per OTHER guidelines?	N/A	N/A	N/A	N/A	N/A	Yes	N/A	N/A	N/A	N/A	N/A	N/A
15	Time (in hrs) rescuers would have made contact with trapped miners	1000 ft: 8-10 2000 ft: 3	48 or less	1000 ft: 48 2000 ft: 40	3 or less	2-32 (?)	1000 ft: 10+ 2000 ft: <1	<21, if present	1000 ft: 5 2000 ft: 4.5	96?-with borehole	<5 (?)	6.5-21.5	N/A
16	Would additional outby stations have been beneficial?	No	No	No	No	No	No	Cannot say	No	No	No	N/A	No

3.3.1 Analysis and Conclusions

- Of the twelve disasters given further study, eight involved explosions, three involved fires and one involved a fire with an accompanying minor explosion.

- Of the nine disasters involving explosions, none occurred right at a working face. In the Finley disaster (involving two conjoined mines), the explosion occurred about 150 ft away from one of the working faces but about 1,500 ft away from the other. In the other eight disasters, the explosions ranged from 450 ft to 2,300 ft away from working faces.

- In nine of the disasters, some or all of the victims were originally located at their working faces when the disaster was first discovered. In the other three disasters (all explosions), miners at outby locations triggered the explosions and they were the only miners affected.

- In nine of the twelve disasters, some or all of the miners were sufficiently healthy to attempt escape for a considerable distance. In the other three disasters, miners were apparently injured severely or overcome quickly and traveled only a short distance. Two of these (Oakwood Red Ash and Itmann) involved cases where outby miners triggered the explosions. The third (Finley) involved a violent explosion that instantly killed 33 of the 38 miners affected and the other 5 were only able to travel 100 to 140 feet before perishing.

- _Stations located at 1,000 ft from the face_: in eight of the twelve disasters, the victims would likely have been able to reach a station located 1,000 ft from the faces. In another of the disasters (Finley), it is not know whether the victims initially surviving the explosion could have reached a station at 1,000 ft because data is not available on the extent of their injuries. In another two of the disasters (Oakwood Red Ash and Itmann), the victims would only have been able to reach a station at 1,000 ft if it were close by due to their injuries. In one of the disasters (Pyro No. 2, in abandoned works), the sole victim could have reached a station at 1,000 ft (if it still existed in the area) but would probably not have stayed because he would have been in fresh air.

- _Stations located at 2,000 ft from the face_: in six of the twelve disasters, all or some of the victims would likely have been able to reach a station located at 2,000 ft from the faces. In two of the disasters (Itmann and Blacksville), all or some of the victims would _not_ have been able to reach a station at 2,000 ft due to their injuries or mine conditions. In two of the disasters (Sago and Pyro William Station), it can't be determined for sure if the victims would have been able to reach a station at 2,000 ft based on their injuries or mine conditions. In one of the disasters (Oakwood Red Ash), the sole victim would only have been able to reach a station at 2,000 ft if it were close by due to his injuries. In one of the disasters (Pyro No. 2, in abandoned works), the sole victim could have reached a station at 2,000 ft (if it still existed in the area) but he probably would not have stayed because he would have been in fresh air. In the Finley disaster, a station at 2,000 ft would not have been provided due to close proximity to the mine portals.

- *Stations at 1,000 ft from faces versus stations at 2,000 ft from faces*: for five of the disasters, a station located at 1,000 ft would have been preferred over the 2,000 ft location. In two of the disasters, the station location at 2,000 ft would have been preferred and in another two, neither would have been preferred over the other. In two other disasters, it wasn't possible to say if one would have been preferred based on data available. Finally, in two of the disasters the question was not applicable because stations would not have been used in one of them and a station at 2,000 ft would not have been provided in the other.

- *Alternate station locations*: in only one of the disasters could it be said that an alternate station location would have been preferred over the 1,000 ft or the 2,000 ft locations. In the Scotia disaster, miners within their working section off the main entries were trapped inside their section due to an explosion that occurred out in the main entries inby their location. In such cases, it would have been preferable to maintain a refuge station some distance inside the section away from the junction with the mains. Although it is not possible to predict ahead of time that a disaster of this nature might occur, it might be a sensible protocol to establish a station within a dead-ended working section just as soon as possible after the section has advanced deeply enough to accommodate it. The Sago disaster bears this out as well; a location within 1,000 ft from the working faces at Sago would have been inside the section away from the direct firing line of the explosion and an ideal location for a refuge station. Because the submain was less than 2000 ft long a station at 2,000 ft from the faces at Sago would have been in the main panel and closer to the explosion and much more difficult for the miners within the section to reach. Note, however, that a station would never have been placed close to a gob seal because of exactly what happened at Sago.

- *Effects of flame on stations at 1,000 ft from faces*: in seven of the twelve disasters, flames *would not* have impacted a station located at 1,000 ft from the faces. In four of the disasters, flames *would* have impacted a station at 1,000 ft and in one disaster (Blacksville) flames would have impacted a station at 1,000 ft for one working section but not the other.

- *Effects of flame on stations at 2,000 ft from faces*: in ten of the twelve disasters, flames *would not* have impacted a station located at 2,000 ft from the faces, although heat would have been a factor in the Wilberg disaster. In only one of the disasters (Blacksville), flames *would* have impacted a station at 2,000 ft. One disaster (Finley) is not applicable because a station at 2,000 ft would not have been provided due to close proximity to the mine portals.

- *Effects of forces on stations at 1,000 ft from faces*: in seven of the nine disasters involving explosions, forces *would* have impacted a station located at 1,000 ft from the faces. Little numerical data was available as to the extent of the forces but in one explosion (Darby), a station at 1,000 ft would have been subjected to forces of up to 15 to 20 psi. In the Sago and Itmann explosions, a station at 1,000 ft would have been subjected to forces of about 2 to 5 psi and 2 to 4 psi respectively. In the Pyro William Station and Pyro No. 2 explosions, forces *would not* have impacted a station at 1,000 ft (and a station may not have even been provided in the Pyro No. 2 case).

- *Effects of forces on stations at 2,000 ft from faces*: in six of the nine disasters involving explosions, forces *would* have impacted a station located at 2,000 ft from the faces. Again, little numerical data was available but in the Darby explosion we estimate that a station at 2,000 ft would have been subjected to forces of about 2 to 4 psi; in the Sago explosion we estimate it would have been subjected to forces of about 2 to 5 psi and in the Itmann explosion we estimate it would have been subjected to forces of less than 2 psi. In the Pyro William Station and Pyro No. 2 explosions, forces *would not* have impacted a station at 2,000 ft (and a station may not have even been provided in the Pyro No. 2 case). Also, a station at 2,000 ft would not have been provided in the Finley explosion due to close proximity to the mine portals.

In most cases (though not all), stations located at 2,000 ft from the faces would have had the advantage of being further from most of the fires and explosions than a station at 1,000 ft and so less likely to be affected by flame and explosion forces; however, miners would have been able to reach a station at 1,000 ft in more cases than a station at 2,000 ft due to injuries, disorientation, debris in their path and the greater distance to be traveled, so stations at 1,000 ft would have been preferred in more cases as noted above.

- *Time for rescuers to reach miners in stations*: the time that it would have taken rescuers to reach miners taking refuge in a station varied widely across the twelve disasters, ranging from about 2 hours to potentially up to 96 hours where drilling a borehole would be required (see details in the table). Generally, rescuers would reach a station at 2,000 ft from the faces quicker than a station at 1,000 ft due to its location 1,000 ft further outby. In some cases, they would have reached a station at 2,000 ft much sooner (as in the Darby and Scotia explosions) while in other cases there would have been little difference. Obviously it would have depended on the conditions that rescuers would have encountered in the 1,000 ft of advance between the 2,000 ft and the 1,000 ft stations.

- *Additional outby stations*: as to the possible benefits of additional stations located in outby areas (as at one-hour travel intervals to match MSHA's breathable air requirements), there was only one disaster (Oakwood Red Ash) where an outby station might have possibly helped. The two victims were working in an abandoned area of the mine, so an outby station could possibly have been their only recourse had one existed in the area and if the extent of their injuries had allowed them to travel to it. In all eleven of the other disasters, miners either would have used stations at 1,000 ft or 2,000 ft from the faces instead or would not have been able to reach an outby station or would have been in clean air before ever reaching one.

- *Additional recommendations for locating stations*: recommendations related to station positioning surfaced from this study as follows:

  - Both the Wilberg and Alma mine fires were associated with conveyor belt systems. Conveyor belt systems, especially belt drives, are potential friction hot spots and have been sources of mine fires in the past. Avoid locating stations within escapeway crosscuts that are close to belt drives or other potential fire hot spots. Past mine fires and explosions have also often destroyed ventilation overcasts so station locations near overcasts should also be avoided.

  - The Blacksville No. 1 mine fire occurred in the track entry on equipment being moved in the entry. Fires and explosions have occurred in track entries in the past due to the prevalence of equipment, supplies and moving electrical and mechanical systems along the track. Although MSHA regulations [3] preventing the movement of equipment while miners are located inby will prevent similar disasters in most cases, another suggestion for station positioning would be to avoid locating them within or off track entries when other options are available.

  - The Oakwood Ash and Pyro No. 2 mine explosions both suggest that it could be important to maintain stations at either 1,000 ft or 2,000 ft from abandoned or mined out areas of mines as long as there is likelihood that miners will still need to access those areas, even if only occasionally, particularly since they may not be as well ventilated as more active working sections. Only a single station would be required since the section would no longer be advancing and the 1,000 ft location would be preferred since the greatest likelihood of an ignition or explosion would be in or near the abandoned face areas.

  - Based on the Sago disaster and general mining engineering judgment, stations should not be placed near gob seals.

- *Questions regarding station use and deployment*. It appears that some mines in the country are opting for portable stations (chambers) that have to be deployed for use. MSHA currently requires material to build an airtight barrier and will require rapidly inflatable walls when they become commercially available for breathable locations [4]. The reasons for such concepts for stations are obvious: the stations would be much easier to move as mining advances; however, our analysis of the mining disasters from 1970 to the present have shown that many of the disasters involved injured miners, most involve poor visibility due to dust and smoke and many have miners donning self rescuers. In fact, many miners under the duress of a mine emergency have had trouble performing the simple task of opening and donning a self rescuer. This leads to key questions that need to be addressed regarding the use of stations that would need to be deployed by miners during a disaster:

- How difficult are such stations to deploy, how long does it take and how much training is required to deploy them?

- How are injured and disoriented miners going to deploy the refuge stations or the inflatable walls if they barely make it to the station and are in dense smoke or dust when they get there?

3.4 Recommendations for Placement of Refuge Stations in Underground Coal Mines

Based on the Phase II research conducted above, following is a summary of our final conclusions and recommendations on the placement of stations within underground coal mines:

- In the cases of many of the disasters studied, stations would have been most effectively located within 1,000 ft from the faces of mining sections while in other cases stations would have been more effective at the 2,000 ft locations, so there are two choices: place stations at both locations or provide one about 1500 ft. It is not possible to maintain consistent distances (e.g., 1000 ft) at all times because the working section is continually advancing as coal is produced. Hence, the station(s) should be situated in *nominal* locations. In the approach using only one station it would be located within a range of 1000 ft to 2,000 ft from the face. Similarly, in the two station option one would be located in range of 500 ft to 1500 ft and the other within 1,500 ft to 2,500 ft from the face.

- It will always be necessary to maintain at least one active station for a working section at all times. A portable chamber cannot be considered "in-service" when it is being moved because its location will be changing and miners will not necessarily know of its in-transit or new final location. In addition, it may be subject to significant damage should an event occur while unanchored or in transit and rendered useless. Therefore, if a one-station system is being used it would require being moved during non-working shifts. If a mine is maintaining a two-station system for a working section, one can be dismantled and moved while the other station remains in service. This would apply whether the stations were portable chambers or bulkhead-based stations. Two basic scenarios that could be employed for this:

1. _Alternating stations_: as the inby station begins to reach a distance of 1,500 ft from the faces (and the outby station approaches 2,500 ft from the faces), the outby station would be relocated to a position approximately 500 ft from the faces and the previously inby station would then become the new outby station. This cycle repeats as mining advances. If both portable chambers and bulkhead type stations are used in this scenario, they would alternate in their positioning.

2. _Series station advancement_: as the inby station begins to reach a distance of 1,500 ft from the faces (and the outby station approaches 2,500 ft from the faces), the inby station would be moved up to a position approximately 500 ft from the faces while the outby station remains in service. Once the inby has been relocated and is back in service, the outby station would then be moved up to a new position about 1,500 ft from the faces. This cycle also repeats as mining advances.

- The above recommendations would apply to retreat longwall and pillar mining as well as to forward development mining. In cases of retreat mining, the stations would simply be relocated in the outby direction rather than the inby direction as mining progresses. Retreat mining could allow the reuse of abandoned bulkhead type stations that had been set up during earlier development mining.

- Note that special consideration has not been given to very low coal seams in this recommendation. Mines may need to consider placement of refuge stations within ranges closer to the faces on a case by case basis depending on the height of their coal seams or on other mitigating factors that would make travel to a station particularly difficult during emergency conditions of poor visibility and potentially bad atmosphere.

- In sections such as longwall sections where miners are spread widely throughout the face area and alternate escape routes are provided (as in headgate and tailgate escapeways), stations should be provided within each of the main escapeway routes where feasible. In the case of longwall tailgate entries, this may not be possible given the caved entries from adjacent mined out panels and dense cribbing installed to provide support in those entries.

- Stations should obviously be located within crosscuts off standard designated intake escapeways. If necessary in some instances, they may be located off designated return escapeways.

- None of the disasters studied suggested a specific station location that would obviate the 1,000 ft , 1,500 ft or 2,000 ft options. Hence, we are not recommending any specific alternative locations; however, we recommend establishing an initial station within a dead-ended working section as soon as possible after the section has advanced deeply enough to accommodate it. This will provide refuge to miners who could become trapped within the dead-ended section by fires or explosions that might occur either inby or outby in the adjoining main entries.

- The likely timeframe required for mine rescuers to reach miners trapped in a refuge station varied widely in the disasters studied. In at least one disaster, it could have taken rescuers up to 96 hours to reach trapped miners through a borehole. In many other cases it took substantially less time to reach trapped and injured miners. We recommend that stations be equipped to handle stays of up to 96 hours to accommodate the outside range of the rescue timeline and to account for the potential for stations to be overloaded (over designed capacity).

- Our study has shown that additional outby stations would only rarely be helpful in sustaining miners escaping a mine disaster and we do not consider maintaining outby stations to be a necessary requirement. However, mines providing boreholes at regular intervals as mining progresses (typically under minimal cover with ready access to all surface areas) might consider maintaining stations at intervals within the mine based on the relative ease in doing so. In a severe disaster, they could certainly provide temporary refuge to escaping miners to regroup and rest as they continue their escape.

- Stations should not be located within escapeway crosscuts that are close to belt drives or other potential fire hot spots. Past mine fires and explosions have also often destroyed ventilation overcasts so station locations near overcasts should also be avoided.

- Fires and explosions have occurred in track entries in the past due to the prevalence of equipment, supplies and moving electrical and mechanical systems along the track. MSHA regulations (initiated based on the Blacksville No.1 fire and explosion) prevent the movement of equipment while miners are located inby. Nonetheless, stations should not be positioned within or off track entries when other options are available.

- Stations should be maintained at either 1,000 ft or 2,000 ft from abandoned or mined out areas of mines as long as there is likelihood that miners will still need to access those areas, even if only occasionally, particularly since they may not be as well ventilated as more active working sections. Because mining will not be occurring in such inactive areas, stations will obviously not need to be relocated within those areas.

7

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February 27, 2008

Jeffery L. Kohler
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Dear Mr. Kohler:

The West Virginia Mine Safety Technology Task Force would like to take this opportunity to thank you and all the NIOSH researchers involved in the testing and evaluation of the four shelters and your recent report on refuge alternatives for underground coal mines. We realize that it is often difficult to "break new ground" and appreciate your willingness to be involved.

The Task Force recently reviewed the report and wanted to note some areas of concern and ask for clarification on some issues. They are as follows:

1) The Task Force would note that in Table 1 on page 6 of the report for Occupant-Activated Annunciation the recommended value or practice is to utilize a battery-powered strobe light or radio homing signal. The battery powered strobe light was originally required under WV Senate Bill 247 which became law in 2006 and was noted in the corresponding rules developed for this law. We have since made a recommendation to Director Wooten and Governor Manchin that this should be removed. Presently such action is in bill form and moving through the WV Legislature with expected passage. The concern is that the risk presented by the battery as a secondary ignition source is greater than the value it presents to potential rescuers. The same may be true for the case of radio homing signals.

2) Also in Table 1 on page 6 the minimum distance to the working face recommended value of 1,000 feet is also an area of concern. As you may know, WV regulations require that the emergency shelter be kept **within** 1,000 feet (maximum) of the nearest working face. As you can see, this is a conflict with current WV regulations. Our thought process was to have the shelter fairly close by as most cases of entrapment from the literature were caused by events outby rather than in the general face area and if the pressure is great enough to cause damage to the shelter (greater than 15 psi), the probability that someone is still alive to utilize the shelter is very low.

Jeff Kohler
February 27, 2008
page two

3) On page 8 of the report in the third paragraph the statement is made that shelters should be placed in the crosscuts rather than the entries and not located in or off of the track entries. This is problematic in that a three entry development system you quickly are eliminating possible locations. Second, the Task Force is in agreement that damage from handling the units to locate them in crosscuts and to "keep up" with the face is of higher probability than damage if it is located in the entry (rationale at the end of item 2 also applies).

4) There is also concern over recommended values for unrestricted floor space (>15 square ft) and unrestricted volume (>85 cubic ft). These values may exceed some of the portable shelters currently providing protection in underground mines in West Virginia. Did you mean for this value to apply to portable shelters and in-place shelters or only in-place ones?

5) Also in Table 1 on page 6, the footnote on communication with the surface (#13) states that these systems should be independent of the mine's communication system, to the extent practicable. The Task Force has envisioned that communications should be integrated for the primary reason that if it is used everyday you know that it is functional when you need it. If it is a separate system there is concern that it will not be functional when needed most.

Again we want to thank you for your efforts and would welcome the opportunity to discuss these issues with you and/or members of your staff at your earliest convenience. We would like to continue working with NIOSH and MSHA as MSHA begins work towards proposing rules on shelters and hope that MSHA would consult state agencies in the initial formulation.

Sincerely,

Ronald L. Wooten, Chairman

James Dean, Co-Chairman

Theodore Hapney, Labor Representative

Dale Birchfield, Industry Representative

Gary Trout, Labor Representative

Terry Hudson, Industry Representative

Stephen Webber, Labor Representative

J. Todd Moore, Industry Representative

COAL MINE RESCUE AND SURVIVAL SYSTEM

VOLUME I

SURVIVAL SUBSYSTEM

FINAL REPORT

September 1971

Prepared for

BUREAU OF MINES
U.S. Department of the Interior

Under Contract H0101262

By

WESTINGHOUSE ELECTRIC CORPORATION
Special Systems
Baltimore, Maryland

TABLE OF CONTENTS

Section | Page

LIST OF ILLUSTRATIONS

CHAPTER 1
INTRODUCTION

CONTRACT INFORMATION

This volume constitutes the Survival Subsystem portion of the final report for the Coal Mine Rescue and Survival System (CMR&SS) program, which was conducted by the Westinghouse Electric Corporation under contract to the United States Bureau of Mines (Contract Number H0101262 dated June 17, 1970). The program was directed by the Special Systems Department of the Westinghouse Baltimore, Maryland, facility.

The basic objectives of the CMR&SS program were to develop and test hardware to determine the efficacy of a variety of coal mine rescue and survival concepts and techniques. These concepts were drawn from two major sources: the Request for Proposal from the Bureau of Mines[1] and the final report on the Mine Rescue and Survival Study conducted by the National Academy of Engineering[2] (NAE).

Both of these documents recommended that the overall Coal Mine Rescue and Survival System comprise three subsystems; the Survival Subsystem, the Communications Subsystem, and the Rescue Subsystem. These subsystems are covered by Volumes I, II, and III, respectively, of this final report.

Each of the major tasks, corresponding to the three subsystems, was conducted by a subcontract organization. The Westinghouse Ocean Research and Engineering Center, in Annapolis, Maryland, was selected to conduct the design and development effort on the Survival Subsystem because of their wide experience in life support technology. The Westinghouse Geophysical Research Laboratories, in Boulder, Colorado, specializes in the technologies required for the Communications Subsystem, and they were selected for this part of the system. The Rowan Drilling Company, Inc., of Houston, Texas, was responsible for the work on the Rescue Subsystem.

The program was completed within the extremely tight time constraints required by contract, and it culminated in demonstrations of the Communications and Rescue Subsystems at the US Steel Mine number 14, southeast of Gary, West Virginia; and of the Survival Subsystem at the Bureau of Mines experimental and safety research mine at Bruceton, Pennsylvania.

PROGRAM BACKGROUND

During the period from 1950 to 1969, there were 28 major mine disasters (i.e., five or more deaths) and several minor accidents (fewer than five deaths) that resulted in a total of 644 deaths in the United States during this period. In those cases in which cause of death is known, 20 percent could have survived by knowing escape routes through training, by using self-rescuers, or by barricading, according to the NAE report.

In mine explosions, lethal gases are forced throughout the immediate area, the oxygen level is reduced, stoppings are destroyed, and normal ventilation is disrupted. The regular communication system is often destroyed. While trying to escape after an explosion, miners are apt to encounter lethal gas.

GENERAL SYSTEM DESCRIPTION

The Survival Subsystem is divided into three parts; a Personal Breathing Apparatus, an Auxiliary Survival Chamber, and a Large Central Chamber. The Personal Breathing Apparatus is a unit lighter and more compact than the units used by rescue teams, originally intended for miners to carry at all times, which provides oxygen for a breathable atmosphere and a full head mask for protection from toxic gases. The Auxiliary Survival Chamber is a transportable unit that is maintained close to actual working areas. It provides basic life support for 15 men for 14 days. The Large Central Chamber is conceived to be permanently installed in a central location in the mine, providing life support for 50 men indefinitely. These Survival Subsystem units are covered fully in this volume from the viewpoint of design, manufacture, test, and evaluation.

The Communications Subsystem provides three major functions; communications from the miners to the surface, and location on the surface of a position directly above the trapped miners. This location is used as the basis for the actual rescue operations. An electromagnetic system provides downlink (surface to miner) communications, with a voice receiver in the survival chamber and on the miners' battery packs. A beacon transmitter in the survival chambers can transmit six pushbutton selected coded messages, thus enabling miners to respond to questions from the surface.

A seismic signaller (thumper) is also provided as backup to the electromagnetic and communication system elements. Seismic reception and data processing capabilities on the surface are the principal elements used to determine the location of the drilling site. The Communications Subsystem is the subject of another volume of this report which completely describes it, including the interfaces with the Survival Subsystem.

The Rescue Subsystem consists basically of two complete drilling rigs, with all ancillary equipment, for drilling two holes directly from the surface to the trapped miners. The first is an 8-3/4 inch probe hole, used to locate the miners and to supply air, food, water, medical supplies, and other immediate needs. The other hole is a 28-1/2 inch hole, through which a rescue basket is lowered to pull the miners to the surface. Another volume of this report provides a complete discussion of the Rescue Subsystem.

SURVIVAL SUBSYSTEM DESCRIPTION

Personal Breathing Apparatus

The Personal Breathing Apparatus (PBA) is an emergency unit designed to provide a breathable atmosphere in a contaminated gaseous environment, particularly in coal mines, into which carbon dioxide, carbon monoxide, and other gases are released by fire or explosion. It is a closed-circuit oxygen-generating recirculating system that is worn on the chest when in use, with a strap around the shoulders and waist and a hood over the head. When not in use, it hangs from the shoulder by a strap within a hermetically sealed carrying case. The PBA uses a sodium chlorate candle to produce the oxygen. This candle is ignited after the apparatus is removed from the carrying case for use, and it is fitted with a shield to protect the user from heat. Oxygen is produced at a rate sufficient for a typical adult man working at maximum effort level. The oxygen passes via filters, heat exchanger plates, and the CO_2 scrubbing canister, into the breathing bag. The user breathes through a valved mouthpiece so that when he inhales, CO_2 is scrubbed, and O_2 laden gas is drawn from the breathing bag, and when he exhales, the exhaled gas passes into the exhalation side. From here the CO_2 laden exhaled breath passes through a carbon dioxide removal canister, while filtered oxygen is released into this same chamber. Excess gas mixture is vented through a relief valve if the man is not at maximum activity, because the chlorate candle is a fixed rate producer of oxygen. The PBA candle will liberate oxygen for approximately 1 hour.

A plastic hood, treated to prevent fogging in the eyepiece area, fits over the user's head. A rubber seal around the neck prevents entry of contaminated gases. The mouthpiece seal permits the user to remove the mouthpiece for intermittent communication. A nose clip is built into the hood to aid in the prevention of nasal inhalation.

The PBA (exclusive of breathing bag and hood) is 3.5 inches deep, 9 inches high, and 11 inches wide, and weighs 6.9 pounds in the operational mode. It is hermetically sealed for storage prior to use. Temperature may vary from -40 to + 140°F during storage without affecting operation of PBA. In the stored mode, it weighs 8.5 pounds and measures 4.5x12x11 inches.

Auxiliary Survival Chamber

The Auxiliary Survival Chamber (ASC) is a portable self-contained 15-man refuge for trapped miners. It is to be located near the working face in a place that affords it some protection from explosion and where it will not interfere with normal mining operations (e.g., an unused crosscut). In concept, it will usually be located 350 feet or more from the working face, and should be moved at approximately 2-week intervals, or as required to remain reasonably accessible to its associated working section personnel.

The ASC contains two atmosphere conditioning units that, through hand-operated pumping of the internal atmosphere, adds oxygen and removes carbon dioxide. Provisions for clearing initial or leaking carbon monoxide can also be accomplished with these units. The ASC contains enough food and water to supply 1,740 high-carbohydrate calories and 2 quarts of water per man per day. Sanitation facilities are included and equipment is provided to measure concentrations of carbon monoxide, carbon dioxide, methane, and oxygen in and immediately around the ASC. Fire-fighter and first-aid supplies are also included. Lighting is provided by battery-powered miner's cap lamps attached to a storage battery system. Chemical light packages are also included as a backup. Interior surfaces are white to make maximum use of available light. Provisions are included for the installation of Communications Subsystem equipment.

Each of the two atmosphere conditioning units in the ASC has a built-in breathing manifold with eight breathing masks. These are used if the interior atmosphere is contaminated, such as may be the case after initial entrance. If the chamber is not contaminated, the manifold is removed and the oxygen is freely released. The atmosphere conditioning units use sodium chlorate candles to produce oxygen, a Hopcalite canister to remove carbon monoxide, and a baralyme canister to remove carbon dioxide.

In operation, turning the blower draws in air from the ASC through the carbon monoxide and carbon dioxide removal canisters. The scrubbed air and candle-generated oxygen are then released into the ASC, or into the breathing manifold and masks.

The ASC consists of six matched pairs of arcs from a semicircular configuration. They fold down from hinged joints attached to the reinforced platform floor to which wheels can be fitted. The shells are curved and attached at the top to form a quonset-hut-like structure. Seals are provided throughout the chamber in an effort to minimize leakage. Two end bulkheads that also fold down for transport are bolted and braced into place when the shelter is erected. One bulkhead contains the entrance door and a viewing port. When assembled, the ASC is designed to withstand explosive forces of 20 psi (uniform loading) and roof falls up to 1,000 psf.

<u>Large Central Chamber</u>

The Large Central Chamber (LCC) is a design for a permanent fixed installation to provide life support for as many as 50 men indefinitely. In concept, it would be located so as to offer greatest accessibility to the largest number of miners, assuming the main exit shafts are closed or inoperative.

The LCC contains food and water for 1,740 high carbohydrate calories per day for 50 men and 3 quarts of water per man per day. Sanitation facilities are included. Equipment is provided to measure the concentration of carbon monoxide, carbon dioxide, methane, and oxygen in and immediately around the LCC. Fire fighting and first aid supplies are also included. Miners can communicate with the surface through sound-powered phones. The LCC is connected directly to the surface through a ventilation borehole that can be used to supply air, food, water, medical supplies, temperature control, and other needs. If an emergency situation closes this borehole, the supplied atmosphere conditioning units can maintain a breathable atmosphere for the 50 men for 5 days. This should allow time to reopen the borehole so that the ventilating and cooling equipment on the surface can take over the life support functions. Spare PBA units are also included in the LCC for use in missions outside the chamber.

The surface ventilating equipment consists of an air-cooling unit and thermostat, a compressor, a duct air heater and thermostat, and a supply hatch in the shaft. The borehole is 8 inches in diameter, fully cased. In operation, the compressor drives 800 cfm of cooled (summer) or heated (winter) air through the shaft to the LCC. When pressure in the LCC exceeds 2 inches of water, one-way valves open to exhaust the air into the mine. The air cooling unit is a standard thermostatically controlled evaporator, compressor, and condenser unit. The heater is a thermostatically controlled 6-kW electric heater. The air cooling unit and the heater are interlocked with the compressor so they cannot be operated until the compressor is operating and supplying air.

Five atmosphere conditioning units and a chilled-water air-cooling unit are included in the LCC. The atmosphere conditioning units are essentially the same as those used in the ASC, except that the breathing manifold has 10 masks instead of 8. The air-cooling unit is capable of removing 16,000 Btu per hour. It requires no electricity; it operates on a centrifugal pump that is direct-coupled to the fan, and both are driven by a bicycle pedal arrangement.

The LCC has concrete floor and footings, reinforced concrete blast walls at each end, and an arched galvanized steel liner plate roof. One blast wall has two steel ship-type doors; the other has one. The blast walls are 12 inches thick, while the floor is 5 inches thick (75 feet long, 12.7 feet wide). Footings are 13.35 inches wide and 9.1 inches top to bottom. The ventilation pipe is welded into the roof, which is 12 gauge galvanized steel liner plates. Seals are installed throughout the LCC to maintain airtight integrity. Grouting is injected between the roof and the tunnel walls to ensure maximum support. The LCC is designed to withstand blasts up to 20 psig with no loss of airtight integrity and roof falls up to 1,000 psf. Lighting is battery powered, and provisions are included for the installation of Communications Subsystem equipment.

REFERENCES

All reference materials cited in this volume are listed, in order of their appearance, in Appendix B.

CHAPTER 2
DESIGN

This chapter is a discussion of various facets of the design program which led to the currently configured Survival Subsystems of the Coal Mine Rescue and Survival Systems (CMR&SS).

The general background discussed in Chapter 1 and the long history of coal mining deaths both attest to the urgent need to provide the coal miner with as much assistance as possible in surviving coal mine disasters. One major cause of deaths in these disasters is the presence of toxic gases, another is fires. The Survival Subsystem described herein provides individual and group protection in both these areas.

SECTION I
DESIGN CONSIDERATIONS

GENERAL

The single major consideration in the design of the Survival Subsystem is human survival in an environment that offers little or no natural assistance and may be entirely hostile. To this end, the miner must have some means of receiving a breathable atmosphere while he makes his way to safety. If escape is immediately cut off, there must be provisions for an entire crew to survive while outside rescue efforts proceed. The three-part Survival Subsystem makes all these provisions available. The Personal Breathing Apparatus (PBA) provides a breathable atmosphere for the individual miner; the Auxiliary Survival Chamber (ASC) provides life support for 15 men indefinitely; and the Large Central Chamber (LCC) provides life support for 50 men for 5 days should the borehole be closed as a result of the accident, indefinitely if the borehole can be reopened.

SYSTEM REQUIREMENTS

At the outset of the CMR&SS program, basic requirements were developed from several sources. Principal among these were the Request for Proposal from the Bureau of Mines[1], the NAE final report[2], the Bureau of Mines contract[3], the Westinghouse proposal for the program[4] (made part of the contract by reference), and Section 13E of Title 30 of the Code of Federal Regulations (CFR)[5]. As the program progressed, and the store of pertinent information grew, system requirements changed; some were deleted, while several were added. The initial system requirements and limitations were outlined in the Preliminary Survival System Outline chart (ref. 4, pp 2-62). This document underwent continual updating, having been revised and republished twice. The requirements as they existed at the design-freeze point in the program are discussed in the following paragraphs.

Personal Breathing Apparatus

The basic requirements for the PBA remained unchanged throughout the program. These requirements are that it provide a respirable atmosphere; that it exclude smoke, dust, and toxic gases and protect the face; that it remove carbon dioxide; that it be easy to activate; that it provide safe partial oxygen pressure immediately; and that the fit be essentially universal from the 5th to the 95th percentile of human adult male heads), and that it be small and light enough to be carried by a man.

Originally, one requirement stipulated that the PBA provide a 1-hour oxygen supply for a miner using 3 liters per minute (at labor) or an 8-hour supply for a user at rest. If further required that the oxygen be USP grade and constitute at least 20.5 percent of the breathing air. This latter requirement has not changed; however, the supply requirement was changed to 1 hour, regardless of work rate. This is compatible with CFR, Title 30, Table 4, Test 4, which requires a flow rate of at least 3 liters per minute for 1 hour.

The initial PBA concept called for a circle flow or pendulum flow unit with a superoxide revitalizer. An assured supply of high quality superoxide could not be found and design of the superoxide canister could not meet schedule; therefore, this concept was changed to use a chlorate candle plus a CO_2 removal canister instead of superoxide.

The maintenance of a comfortable breathing air temperature and maximum breathing resistance of 2 inches (5 cm) of H_2O in and 1 inch (2.5 cm) out at 85 liters per minute were both specified from the outset. Because a man whose life is endangered will readily accept some discomfort, these stringent requirements were relaxed to an acceptable breathing air temperature and to 2 inches of H_2O exhaling resistance of no more than the difference between 4 inches and the actual exhaling resistance (ref 5, para 11.21 (2) ii and (4).

Weight and dimension specifications for the PBA were set at 4.6 pounds and 9x8x3-1/4 inches. Since the chlorate candle and canister alone weigh 6 pounds, new design goals were established of 6.9 pounds and 11x10x3-1/4 inches.

Aluminum was to be avoided in the PBA because of a potential thermite reaction on contact with iron oxide.[5A] However, aluminum offers optimum heat transfer characteristics for maintaining reproducible chlorate candle burn rate and duration. Therefore, this restriction was lifted to allow use of aluminum for the outer candle casing. It is, however, shielded by a piece of light perforated plastic from external contact so that the aluminum surface cannot become easily abraded and subsequently undergo a thermite reaction.

The requirements stated that the PBA should permit intermittent voice communications among miners. During the course of the program, it was determined that reasonable communication could be accomplished without the aid of any device as long as the smoke-hood concept for man-apparatus interface was utilized.

Auxiliary Survival Chamber

During the CMR&SS program, a great many of the original requirements and constraints for the ASC were modified; one was eliminated. Provisions for trace contaminant removal, humidity control, temperature control (85°F), pressure relief at 0.75 inches of mercury, and a differential manometer were included at the start.

Trace contaminants, odors, are not a real problem due to rapid fatigue adjustment of the olfactory system. Manometer readings were not needed due to automatic relief provided by design; temperature and humidity control is not critical to this design under typical mine ambient conditions (see Appendix A); therefore, these requirements were excluded.

The ASC was originally required to withstand a 20-psi shock and maintain its airtight seal. Because both positive and negative pressure waves result from mine explosions, this requirement now includes a 5-psi negative pressure.

Using no aluminum was an initial constraint on the ASC, but the penalties this would cause in cost, weight, strength, heat transfer, and delivery schedule for some components made compliance impractical. Therefore, the constraint was relaxed so that aluminum could be used in some components, so long as they were not exposed to vigorous contact with iron oxide.

The ASC structure concept called for it to fit into a crosscut 14 feet wide (bottom), 10 feet wide (top), 7 feet high, and 35 feet long. Information on mine layouts and seam thickness gathered during the program and the need to allow adequate space for each occupant led to change in this requirement. The ASC must now be assembled or disassembled in a crosscut 10 feet wide, 6 feet high (adaptable to 4.5 feet), and at least 50 feet long. These same considerations brought about another structural concept change. The ASC was to be portable, or easily dismantled, and transportable a few thousand feet through openings 3.5 feet high, and 9 feet wide.

The electrical system specifications specified three sealed lamps (25 W, 6.5 V), seven silver-zinc batteries (9800 Wh), one pedal-operated 6V 75Wdc generator, and chemiluminescent light sources for backup. Further analysis determined that, in order to implement compatibility with the communication equipment (Communications Subsystem), a 12-volt supply would be required. The generator specified would have been costly, large, and heavy; whereas zinc-air batteries are less costly and instantly rechargeable simply by mechanical replacement of spent anodes. Because of these factors, the electrical system now includes 3 miner lamp arrays, each having 2 lamps in series protected with a current-limiting resistor, 1 zinc-air, 12-volt battery (96 Ah) with eight (8) recharge kits, and 52 chemiluminescent packets for 2 hours backup each.

Several changes have occurred in the various life support aspects of the original ASC requirements; however, all factors have continued to be based upon supporting 15 men for 14 days (210 man-days).

The Westinghouse proposal called for providing 105 cubic feet per man giving a total of 1,575 cubic feet for the ASC internal volume. Studies by civil defense authorities [6] on the volume per man required in this type shelter and the overall size limitations of the ASC brought about the more generalized requirement that the internal air volume be sufficient for life support and accommodations of 15 men.

The initial estimate for 316 pounds of oxygen supply was increased to 420 pounds of oxygen. The capacity for removal of carbon dioxide was increased from 368 pounds to 432 pounds carbon dioxide. The design capability of scrubbing carbon monoxide down to acceptable levels from high inlet concentrations is partially responsible for this since oxygen is consumed in the Hopcalite conversion of carbon monoxide to carbon dioxide. In addition, the modified supply allows for a higher average metabolic level for chamber occupants than was originally considered.

Accommodations were reduced from seven (7) 2-tier bunks, 15 blankets, and 15 pillows to six (6) 2-tier bunks, 6 blankets, and 12 pillowcases, because the work schedule and general conditions indicate that at least 3 men will be up and engaged in chamber operation activities at all times.

Human wastes were to be rejected through chutes and tubes to the outside; however, to avoid the risk of the added wall penetrations developing leaks, a portable toilet with disposable plastic bags is now specified.

A nutritionally balanced supply of food and beverages equalling 1,800 calories per day per man, including juices and three 35-gallon water tanks (two installed outside, one inside), was part of the initial ASC concept. Selecting military rations as a proven source of nutrition brought the calorie requirements down to 1,740. The 35-gallon water tanks were rejected in favor of twenty (20) 5-1/4 gallon tanks that can all be stored inside and can be used for waste disposal when empty.

Large Central Chamber

Many of the design requirements for the LCC changed during the course of the CMR&SS program;several of these changes coinciding with the same or similar changes in the requirements for the ASC.

Among the more significant changes to the LCC requirements was increasing the 4-day secondary support (with the air borehole to the surface blocked) to 5 days capability. This resulted from drilling studies and tests which indicated that, with the air borehole badly damaged or blocked, 5 days is a more reasonable time allowance for setup and drilling of a new shaft. Specifications and equipment developed for ASC atmospheric control were modified to meet expended handling characteristics of the LCC secondary control.

The Westinghouse Proposal specified a gross space allocation of 170 cubic feet per man, equalling 8,500 cubic feet total for the LCC. This was changed to 137 cubic feet per man, 6,850 cubic feet total, on the basis of civil defense[6] and cost effectiveness.

The same restrictions against aluminum were imposed on the LCC initially as were imposed on the PBA and ASC, and they were changed for similar reasons to those stated in the ASC and PBA discussions.

Structurally, the LCC was initially required to withstand a 20-psig shock and maintain an airtight seal, while the roof was to hold 1,000 pounds per square foot uniform load. The crosscut leading to the LCC carried the same loading requirements. The whole structure was to fit into a 40x20x11-foot area, with all parts transportable through 3x9-foot openings. All parts were to be easily handled, be assembled from inside, and require little or no welding. The loading and blast requirements remain essentially the same, except that an overhang has been added beyond each end bulkhead to protect against roof falls and to keep the access areas relatively clear of obstructions. The shoring of the crosscut is a mine requirement and no longer part of the LCC. To reduce costs and provide better heat conduction and ventilation, the basic envelope of the LCC has changed; therefore, space requirements for the LCC are now a 75 x 14 x 8 foot area, with parts transportable through 3 x 5 x 9 foot openings.

With the air borehole operative, atmospheric control for the LCC is accomplished from the surface. The surface equipment was originally expected to deliver 650 cfm of air at 75°F and 55 percent relative humidity (RH); however, the cooling unit must maintain the internal temperature between 40 and 85°F. The 650 cfm flow was deemed insufficient for the cooling requirements, and was therefore increased to 800 cfm.

Water, power, and atmospheric monitoring were also originally part of the surface requirements. Water, power, and monitoring equipment are now installed within the LCC as this approach is both more cost effective and less vulnerable to accidental failure (borehole collapse).

Food requirements in the LCC are the same as for the ASC, and the same type of military rations are used. The original LCC requirements for four 35-gallon water tanks (two outside, two inside) were rejected in favor of eleven 17-1/2 gallon cans inside the chamber. The cans are readily available and can be used for waste disposal when empty.

Accommodations in the LCC called for twenty-one 2-tier bunks, 12 straight chairs, 4 reclining chairs, two 6-man folding tables, 50 blankets and pillows, 2 wash basins, 2 water toilets, 1 chemical toilet, and 4 relief tubes. These remain essentially the same, except for the wash basins, water toilets, and relief tubes. To avoid excessive wall penetrations and to reduce complexity and cost, these items have been eliminated. A second chemical toilet was added for waste disposal.

At the start, 12 lights (110 W, 75V) backed by 3 lights (6V, 25W) driven by pedal driven dc generators (6V, 75W) were required, along with silver-zinc batteries. All switches and lamp housings were to be sealed. As with the ASC, further analysis determined that the most efficient, cost-effective system would be the following: 6 battery-powered lamp assemblies, each having two miner lamps in series protected with a current limiting resistor. Two zinc-air batteries with 16 recharge kits are furnished.

SECTION II
DESIGN IMPLEMENTATION

This section describes the study, design, development, research, and analytical efforts that led to the decisions on the various design aspects of the Survival Subsystem. In these discussions, a complete description of each of the components of the Survival Subsystem is given.

PERSONAL BREATHING APPARATUS (PBA)

The PBA must supply a safe breathing mixture for not less than 1 hour, regardless of ambient atmosphere, for a man working at a high metabolic rate. This requires the availability of an oxygen source. The potassium superoxide (KO_2) originally proposed was further investigated, along with compressed oxygen and chlorate candles. Seven manufacturers of breathing apparatuses were solicited for proposals. Only three responded; two were not responsive to the requirements, and one, Mine Safety Appliance Company, was considered technically responsive, although exceptions were taken both to CFR Title 30 and to schedule/contractual constraints. Therefore, based on a re-assessment of in-house capability and the need for tight developmental control, Westinghouse decided to develop a PBA system in-house, using subcontractors for components. During the conduct of a tradeoff study, KO_2 was determined to be an unnecessarily high risk approach. This, and other factors discussed below, led to the choice of the chlorate candle.

Oxygen Generation

There were three primary candidate systems for generating oxygen in the PBA. These were KO_2, compressed oxygen, and chlorate candles. More exotic systems (e.g., lithium peroxide) were not investigated due to the inordinate amount of development effort involved under schedule constraints.

A tradeoff study based on rated factors of reliability, portability, costs, and schedule was conducted and scored. Table 2-1 shows the ratings and scores assigned the three candidate systems. These four major criteria had previously been broken down into many component subfactors from which the respective ratings were derived. The chlorate candle/LiOH system prevailed primarily because of good scores in all areas related to schedule or development requirements while being at least equivalent with KO_2 as regards subfactors such as maintenance, durability, heat contribution and fabrication cost. The results of this tradeoff combined with lack of assurance in securing acceptable KO_2 chemical or developed KO_2 canister designs, led to the decision for a chlorate candle as oxygen source.

TABLE 2-1
PBA TRADEOFF STUDY ON OXYGEN GENERATORS

CRITERION	%	KO_2 W. Initiator Rating	x%	Chlorate/LiOH Rating	x %	Bottled O_2/LiOH Rating	x%
Reliability	25	705	17,625	690	17,250	605	15,125
Portability	20	650	13,000	270	5,400	0	0
Cost	25	485	12,125	495	12,375	420	10,500
Schedule	30	360	10,800	690	20,750	800	24,000
TOTALS (high score wins)	100		53,550		55,775		49,625

The PBA Chlorate Candle

As shown in figure 2-1, the chlorate candle configuration chosen for the PBA is L-shaped. This geometry facilitates volume minimization in packaging. Alternate configurations considered included two separate, parallel 30-minute duration candle packages and two parallel $NaClO_3$ segments enclosed within the same envelope but connected by means of a "crossover" mixture. The former was rejected due to increased bulk requirements while the latter required undesirable chemical formulation compensation for complex thermal effects induced by the first segment's decomposition influencing burn rate of the segment.

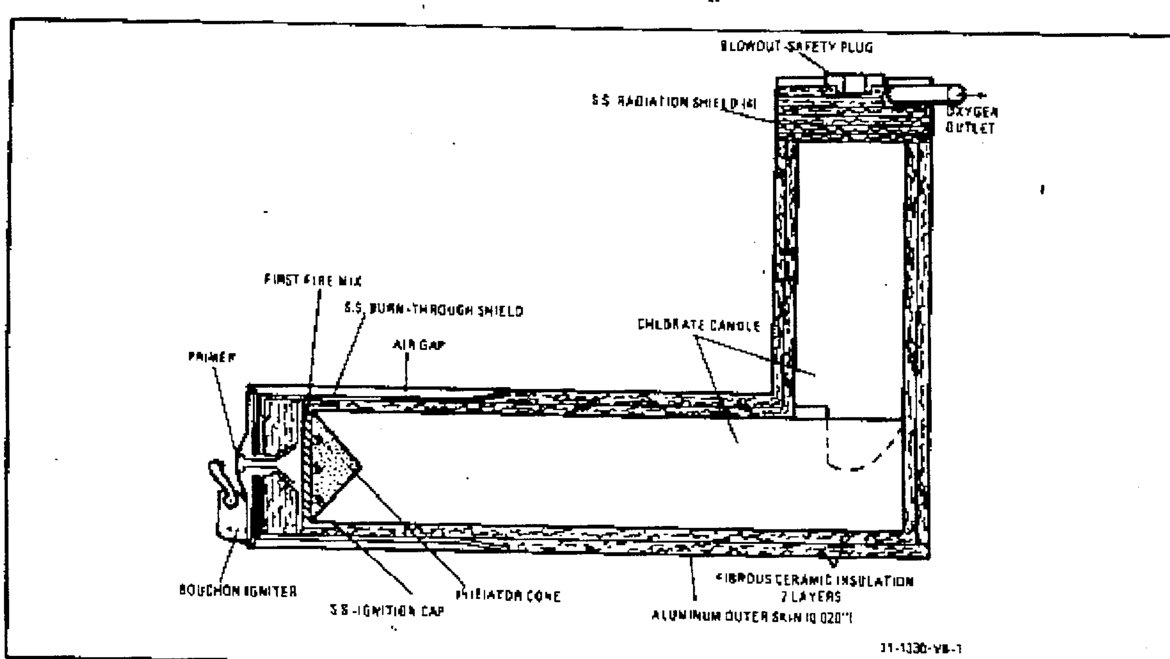

Figure 2-1. PBA Chlorate Candle

Candle activation is a multiple stage requirement. The first stage includes a modified handgrenade-type Bouchon which utilizes a munitions primer immediately producing a flash of hot gases releasing about 800 calories of heat. This heat energy is sufficient to ignite a pyrotechnic "first-fire" composition of zirconium and barium chlorate. The heat energy released by this reaction (~ 500 calories) then ignites a "cone" portion of the oxygen candle, which is a fuel-enriched composition of chlorate. Enough heat is finally generated to initiate and sustain the main portion or "core" composition of the candle. The reaction then proceeds until the supply of chlorate is exhausted. The entire candle is wrapped in layers of a high-temperature resistant, ceramic-type insulation material. The insulation serves to retain sufficient heat within the generator housing to sustain chemical decomposition, and also to help maintain generator wall temperatures within design goal.

This rather fine balance of heat containment (via insulative materials, radiative shields, and air gaps) versus heat dissipation (via skin material selection and surface emissivity) in order to maintain a 350° F maximum envelope skin temperature played the largest role in the magnitude of development required. Too much heat containment resulted in very rapid decomposition, while too much heat dissipation would result in too slow decomposition and at times premature extinquishment of the reaction. Moreover, the balance that was achieved had to be matched to a chemical formulation with heat content sufficient to guarantee reliability and yet meet the flow rate and duration requirements.

These requirements, as stated in Title 30 are as follows: whenever O_2 is produced from a nondemand-type source, flow rate shall be at least 3.0 Standard Liters Per Minute for a duration not less than the stated apparatus duration (in this case, 60 minutes). Our own in-house calculations have indicated that either or both of these requirements could be relaxed (extent dependent on total system volume) and still possess an apparatus that would retain enough residual O_2 in its 4 liter breathing bags to sustain comfortable respiration even under high work rate conditions for the 60-minute duration. However, the Title 30 requirements were retained as contract objectives.

The maximum envelope skin temperature of 350°F was derived from a worst case analysis of coal dust auto-ignition (Bu Mines Report of Investigation No. 5052 Figure 2) in which it is assumed that a coal dust layer composed exclusively of particles <75 microns diameter with 52 percent volatiles content but 0 percent water has collected on the candle surface. Even though it is recognized that this constitutes an improbable situation, this specification also was retained as a design objective.

In order to satisfy these multiple requirements and yet retain reliability, a wide assortment of chemical formulations was evaluated. These included mixtures of low fuel with cobaltous chloride catalyst, mixtures with potassium perchlorate, and mixtures with silicon dioxide inert and several permutuations thereof.

An addition of SiO_2 inert (40 mesh granules) constituted a unique method of stabilizing the decomposition front, thus controlling burn rate. Visual examination of spent clinkers and burns-in-progress confirmed that this incorporation maintained the front in an attitude transverse to the candle axis. Without its presence, the front often progressed in a random fashion, producing large variations in burn rate and consequent loss of duration. No premature extinguishments were experienced over 26 candle decompositions.

It had earlier been established that the preferable container material was black anodized aluminum due to its preferred heat dissipation qualities as contrasted with the more conventional candle container material - stainless steel. The combination of this container with the proper insulative materials and candle formulation produced the construction shown in figure 2-1.

The data accumulated from a series of 6 candle qualification tests indicate that this construction successfully approximated all design objectives: production of the initial 4 liters of oxygen was accomplished within 20 to 35 seconds; burn duration averaged 59.5 minutes over a range of 57 to 64 minutes; and maximum surface temperature recorded at any point was 368°F with most temperatures recorded below 350 degrees.

However, surface temperature of 350°F and duration of 60 minutes cannot be reliably specified as minimum values without further development.

These two parameters can be met by a relatively simple redesign of the container with little or no additional development of the chlorate mix. In fact, solving the temperature problem, which our calculations have shown can be accomplished by the addition of fins to the aluminum casing, should also solve the duration problem since the burn rate of the candle is partially a function of heat dissipation. The more efficient the dissipation, the slower the burn. Should the duration not be achieved with the lower surface temperature, the case could be increased slightly to accommodate increased length of the candle.

Evolved Oxygen Purity

The normal exit path for O_2 evolved from the candle is through flexible tubing attached at the far end of the short leg. Also located in this vicinity is a pressure-relief assembly provided in the event that gas pressure buildup occurs through any possible exit path blockage.

The flex tubing attaches to a separate "U"-shaped gas impurity scrubbing cartridge, which is designed for installation within the inlet plenum of the PBA's CO_2 removal canister as shown in figure 2-2. This scrubbing unit contains baffled beds of Purafil and Hopcalite for removal of chlorine and carbon monoxide, respectively. Its performance has proven quite efficient as shown by gas analysis data in table 2-2. All gas impurity levels are well within standards applicable to breathing mixtures with the exception of carbon dioxide.

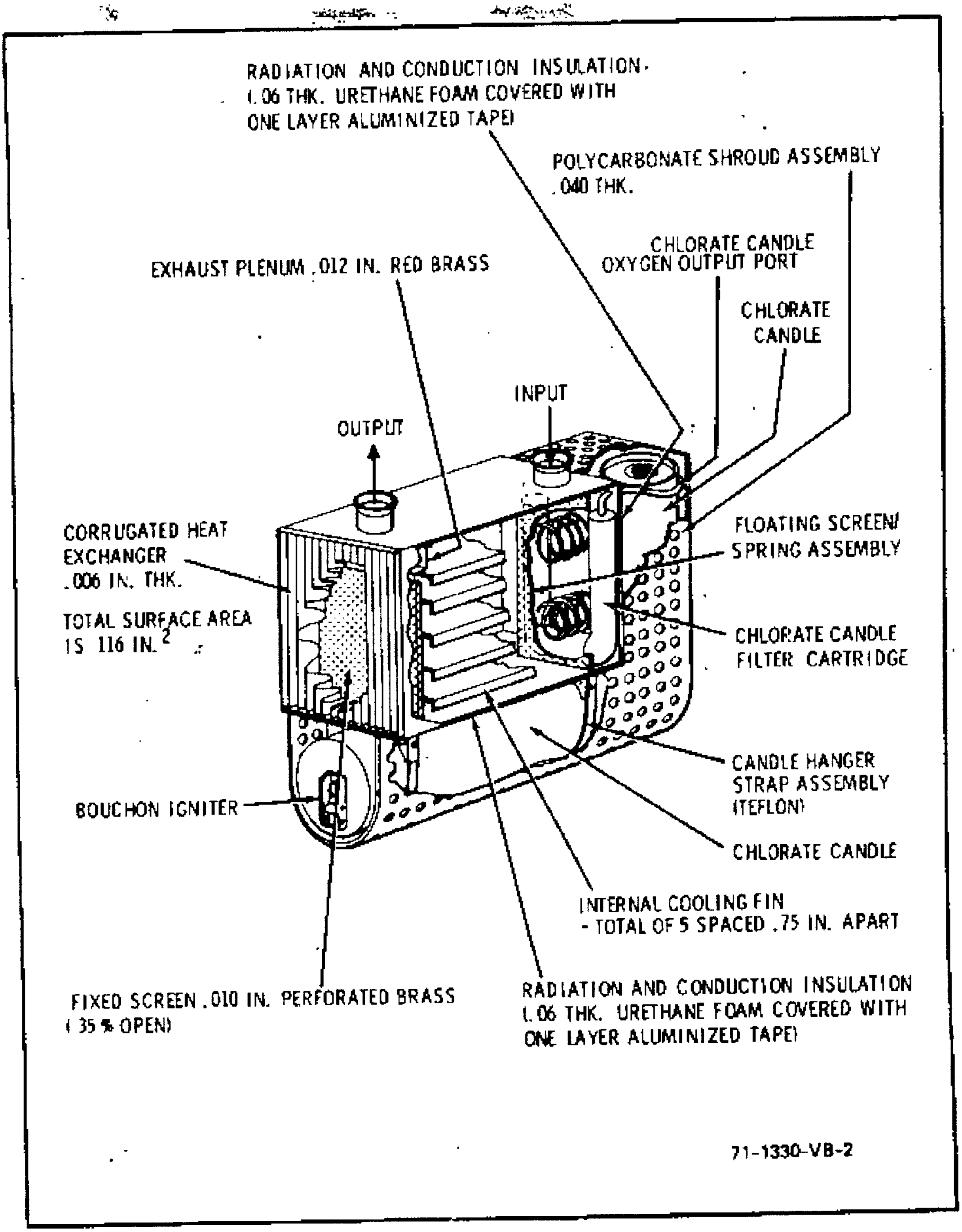

Figure 2-2. PBA Canister/Candle Assembly

TABLE 2-2.
PBA CHLORATE CANDLE GAS ANALYSES

Sample Time (min)	O_2 (%)		CO_2 (%)		CO (ppm)		H_2O (ppm)		Hydrocarbons (ppm CH_4)		Cl_2 (ppm)
	A	B	A	B	A	B	A	B	A	B	A&B
5	99.90	99.93	0.10	0.07	0.60	0.55	0.0	15.0	2.5	6.4	< 0.1
10	99.89	99.92	0.11	0.08	0.65	0.60	5.0	20.0	3.2	6.1	"
15	99.86	99.90	0.14	0.10	0.70	0.70	14.0	35.0	4.2	6.0	"
20	99.86	99.89	0.14	0.10	0.75	0.75	30.0	55.0	4.7	6.3	"
25	99.84	99.87	0.15	0.12	0.90	0.90	60.0	90.0	5.6	6.6	"
30	99.67	99.84	0.32	0.14	1.05	1.10	115	150	6.4	7.3	"
35	99.52	99.77	0.46	0.20	1.30	1.40	190	245	7.4	11.0	"
40	99.52	99.70	0.44	0.26	1.65	1.75	420	405	8.6	11.7	"
45	99.46	99.57	0.46	0.37	2.15	2.30	800	615	9.9	13.5	
50	99.32	99.40	0.62	0.52	2.95	3.15	630	820	12.2	15.7	"
55	99.12	99.15	0.86	0.75	4.85	4.75	200	915	15.0	18.6	"
60	Candle out		Candle out		Candle out		Candle out		Candle out		

Oxygen by Beckman O_2 Analyzer, Model E2.

Carbon Monoxide by Beckman Model GC-5 Gas Chromomatograph (helium ionization detector).

Water Vapor by Beckman Trace Moisture Analyzer P_2O_5 Electrolytic Cell.

Chlorine by General Electric Halogen Detector, Type H.

Hydrocarbons by Beckman Model 109 Flame Ionization Total Hydrocarbon Analyzer.

Carbon Dioxide by Beckman IR 20.

71-1330-T-3

No provision was made within the gas scrubbing cartridge for carbon dioxide removal under the rationale that the lithium hydroxide bed downstream of the cartridge could readily accomplish this task.

Carbon Dioxide Absorbent Selection

Three state-of-the-art chemical absorbents applicable for PBA use, lithium hydroxide, baralyme, and sodasorb, were evaluated in the criteria shown in table 2-3. Lithium hydroxide is by far the most efficient CO_2 absorbent by weight. Its theoretical absorption capacity is 0.92 pounds CO_2/pound absorbent as opposed to a capacity of 0.50 pounds CO_2/pound of baralyme. Its density, however, is quite low, giving it slightly less efficiency than baralyme in terms of volume.

Although LiOH costs more and has a higher heat of reaction than other candidates, these are compensated by the assignment of less development risk. The lower development risk rating was achieved primarily because of preliminary testing done for us by Foote Mineral Co. This testing produced an experimentally derived figure for the amount of LiOH required to meet PBA input conditions.

Even so, the tradeoff overall results were very close. As noted in table 2-3, sodasorb is comparable to all parameters to baralyme. All other conventional CO_2 absorbent systems were considered either less efficient or not applicable to PBA use without entailing undue development risk. Accordingly, lithium hydroxide (LiOH) was selected as the absorption material, primarily because of higher probability of successful development.

LiOH Canister Design Requirements

In contrast to the chlorate candle, which must generate O_2 at a fixed rate based on highest expected work load, the CO_2 absorbent is sized to accommodate fluctuations in work load and the total amount of CO_2 produced. Accordingly, the amount of CO_2 liberated during a 60-minute high work rate program was estimated as shown in table 2-4. This was accomplished by first estimating from Bioastronautics Data Book the O_2 expenditure per activity, totaling the result and applying an average respiratory quotient value of 0.85 to arrive at 82 liters CO_2.

In actuality, a safety factor of nearly 25 percent above this was included in our design considerations in order to cover the following:

1) The stated O_2 consumption rates are estimated for specific tasks and do not account for recovery time required in progressing from greater to lesser work rates.

TABLE 2-3
CO_2 CANISTER ABSORBENT TRADEOFF STUDY

CRITERION 1-5-10	%	LiOH		Baralyme	
		Rating	x %	Rating	x %
1) Sensible heat BTU/ft^3 CO_2 absorbed	10	7	70	9	90
2) Cost Effect on PBA	20	4	80	6	120
3) Non Operational Reliability	15	9	135	9	135
4) Theoretical Weight req'd for 1-hour mission	20	9	180	5	100
5) Theoretical Bulk volume req'd for 1-hour mission	15	7	105	9	135
6) Development Risk (high low)	20	10	200	8	160
TOTALS	100%		770		740

2) Simulation of Title 30 work tasks was accomplished on a bicycle-type ergometer (see table 2-4 for ergometer settings). Since the ergometer requires continual use of the same musculature, recovery times are yet more difficult to estimate.

3) Respiratory quotient (RQ) may reach values of 0.9 to 1.0 at high work rates.

4) RQ may vary dependent on individual test subject. Therefore, in consultation with our Physiology Dept., a figure of 102 liters (0.41 pounds) of CO_2 was estimated as the worst case amount the canister would have to accommodate.

Pressure drop across the canister was another important design parameter. The theoretical plate area based on a 4x14 mesh size reactant material was computed to be 15 sq in based on an instantaneous flow rate of 85 SLPM air and a pressure drop not exceeding 2 inches H_2O. The bed depth, given an experimentally derived figure for required LiOH volume, was computed to be 6 inches. By adopting a canister geometry within these dimensions, we were confident of maintaining pressure drop below 2 inches H_2O at even the highest work rate called out by Title 30 (at which a velocity of 40 SLPM could occur).

Finally, a circle flow breathing circuit was selected over pendulum flow, and axial flow through the canister was selected over radial flow. Since we anticipated some problem in dissipating the heat of reaction generated within the LiOH bed (sensible heat = 875 Btu/lb CO_2), circle flow appeared preferable due to greater opportunity for heat transfer as contrasted to the reduced circuitry of pendulum flow. In addition, pendulum flow would have presented an opportunity for formation of depleted reactant dead spaces within the canister. Axial flow through the canister was chosen primarily because it afforded fewer fabrication difficulties, minimal bulk, and greater opportunity for internal canister modification. Some canister modification in the form of internal finning was contemplated, due, once again, to anticipated heat transfer difficulties. During breadboard testing, it soon became apparent that 5 internal fins would be required.

The body of the canister is made of red brass which has a thermal conductivity of 92 Btu/hr/sq ft/°F. The wall thickness is 0.0126 inches. The amount of heat that will be generated in the canister reaction by a man working to table 2-4, Title 30 computes to be approximately 357 Btu/hr. Considering the worst case of laminar flow convection cooling, which would be the case if the miner were not moving but standing in a stagnant air environment, the exposed surface area of the body of the canister is not enough to transfer this quantity of heat. Therefore, a corrugated heat exchanger surface affording 116 square inches of additional surface area was built into the output end of the canister housing to help cool the effluent breathing gas.

Two plies of Air-Mat No. 12 fiberglass mat are installed over the stationary output end screen to serve as filters for LiOH dusting. The canister is then charged with lithium hydroxide and closed by soldering the end cap at the inlet plenum side; thus compacting the input screen against the bed by means of springs (2 to 3 psi pressure).

Figure 2-2 depicts detail of the internally-finned canister in its final configuration and, in addition, shows how it interfaces with the chlorate candle. The candle is hung under the canister and is thermally insulated from the canister by the Teflon cradle and hanger strap assemblies (two each) and by Urethane foam and Mystik reflective tape radiation and conduction insulation (located on the candle sides of the canister). A 0.040-inch-thick perforated polycarbonate shroud covers the candle assembly offering some slight protection against possible contact burns and protection against abrasion of the aluminum surface while still providing convection cooling for the candle assembly. Not shown in figure 2-2 is a polycarbonate standoff on the back face of the canister which protects the wearer against canister surface temperatures.

Carbon Monoxide Removal

Since there is some chance of the miner being exposed to carbon monoxide (CO), a CO scrubber was considered for inclusion in the PBA. However, the PBA is designed to generate 4 liters of oxygen within 30 seconds which means that by the time the user has the rig donned and is ready to draw his first breath, the breathing bags will be filled with 4 liters of oxygen. Man's

TABLE 2-4
O_2 CONSUMPTION/CO_2 LIBERATION ESTIMATE FOR
TITLE 30, TEST 4, TABLE 4 WORK SCHEDULE

Activity	Time (min)	SLPM O_2	Total O_2 (ℓ)	Total CO_2	Ergometer Setting (Kiloponds)
1) Sampling & reading	2	0.7	1.4		0
2) Walk at 3 mph	2	1.2	2.4		1.5
3) Climb 75° treadmill	1	2.5	2.5		3.5
4) Walk at 3 mph	2	1.2	2.4		1.5
5) Pull 45 lb. wt. 5 ft. 60 times	5	2.1	10.5		3.0
6) Walk at 3 mph	3	1.2	3.6		1.5
7) Carry 50 lb. wt. over overcast 4 times	8	1.9	15.2		2.75
8) Sampling & reading	2	0.7	1.4		0
9) Walk at 3 mph	4	1.2	4.8		1.5
10) Runs at 6 mph	1	2.7	2.7		3.75
11) Carry 50 lb. wt. over overcast 6 times	9	1.9	17.1		2.75
12) Pull 45 lb. wt. 5 ft. 36 times	3	2.1	6.3		3.0
13) Sampling & reading	2	0.7	1.4		0
14) Walk at 3 mph	6	1.2	7.2		1.5
15) Pull 45 lb. wt. 5 ft. 60 times	5	2.1	10.5		3.0
16) Carry 45 lb. wt. walking at 3 mph	3	1.9	5.7		2.75
17) Sampling & reading	2	0.7	1.4		0
TOTAL	60		96.5	82 liters	

71-1330-T-4

lung capacity is comparable to the PBA's volume thus after a few short breaths of about a liter each the CO exhaled will be diluted at least 50 percent. The oxygen generation rate is at a minimum of 3 liters per minute which exceeds the amount that man can continuously consume. This excess, which is vented, will carry with it some CO causing further dilution of CO in the breathing mixture. Further operating instructions (refer to Chapter 3 Section 1) for the PBA require that the user exhale fully before donning the unit; so the likelihood of his lungs retaining an appreciable amount of CO is further reduced.

Not only does it appear by this analysis a reasonable risk to exclude CO scrubbing capability from the PBA, but inclusion of such capability would be complicated and costly. For example, the addition of a CO scrubber such as Hopcalite to the PBA also requires the addition of dessicant to prevent poisoning of Hopcalite by water vapor. However, input water vapor is essential to efficient operation of the lithium hydroxide bed. Therefore, dessicant, by reducing water vapor level within the apparatus, would be expected to adversely affect CO_2 scrubbing capability.

Based upon this analysis, the lack of CO removal provisions was considered both a reasonable risk, and a cost-effective decision.

Contaminant Sources

All parts and materials used in the PBA underwent test and analysis for possible contamination of the breathing gas, with special emphasis on the solder and flux used in final welding and on the fiberglass filter. The flux used (Nokorode Soldering Paste, Federal Specification O-F-506) presents no hazard primarily because it is present in very small quantities and upstream of the LiOH bed, which would absorb any contaminants generated therefrom. In addition, flux ingredients will not vaporize under PBA operating conditions, and even if they did, the vapor toxicants are not at dangerous levels. The solder (National Lead Company, Dutchboy SN-50) also presents no major difficulties, because although both antimony and lead are present in the solder, their potential for ingestion (respiratory or digestive) is practically zero. There is almost no formation of caustic solution in the PBA in which these elements could dissolve and neither element could vaporize under PBA operating conditions. The fiberglass in the filter is tightly packed and chemically bound and, moreover, is compacted under 2 to 3 psi against a perforated backup plate. Therefore, pickup of fibers by air flow is highly improbable. A reasonable conclusion is therefore derived that the present PBA design constitutes no undue hazard as a contaminant source.

Man-Machine Interface

For the PBA application, interface requirements included not only the means to conduct breathing gas to and from the man but also to allow communications, provide visibility, and prevent inhalation through the nose. Other factors considered were universal fit, dead space, comfort, cost, weight and bulk, and development risk. The tradeoff study (table 2-5) considered the use of six different interface means as follows: (1) mouthpiece, (2) smoke hood, (3) oral mask, (4) oral-nasal mask, (5) full face mask, and (6) fright mask. The study showed that for this application the smoke hood is the best choice.

The vendor selected to manufacture the PBA hood was the G. T. Schjeldahl Co., which had previous experience with this type of product and had worked with the FAA on hood developments. However, the PBA hood was a new development in view of the requirements for incorporation of a mouthpiece and eyepiece and means to prevent fogging. The original concept to solve the fogging problem was incorporation of an eyepiece of CR-39 allyldiglycolcarbonate into the hood and application of the antifogging compound "DeMist" manufactured by A.I.D. Ltd. This combination was the result of an extensive literature search and contacts with NASA and the U.S. Army Night Vision Laboratory. However, difficulties were encountered in applying "DeMist" to the selected standard MSA lenses. In order to meet delivery commitments, an alternative compound, Hydrazorb (also from AID) was selected for application on cellulose acetate butyrate lenses; this coating ranks right behind "DeMist" in NASA ratings.

Other hood materials selected included a 1.5-mil laminated construction of Mylar® for the hood proper and a polyurethane elastometer for neck seal. The eyepiece was laminated to the inside surface of the hood so that all hood materials in direct contact with ambient atmosphere are of the self-extinguishing category. The nosepiece is designed as an integral part of the lens and is constructed of nylon, while the mouthpiece is constructed of polyvinylchloride.

Acceptance testing performed on the hood included bond strength of lens, bond strength of mouthpiece, haze of lens, luminous transmittance of lens, pressure drop through mouthpiece, and leak integrity of neck seal. All specifications were met.

The bond strength tests performed on the mouthpiece actually constituted a test of hood tear strength as its weakest design point. The nature of the hood material is such that its resistance to tearing is least at penetration points such as at the mouthpiece or at puncture points, either of which may serve as stress concentration loci for tear propagation. It was found that the mouthpiece could withstand substantial force applied against it whether from a sudden or gradual load. The Instron tensile tester with a cross head speed of 2 inches per minute registered a force of 33 pounds when the hood material was torn away from the mouthpiece. With the sudden drop of a 10-pound weight attached to the mouthpiece, a terminal velocity of 1.64 ft/sec was required for hood material failure. It is not feasible to conduct controlled laboratory examination of all parameters which could contribute to hood material failure such as presence of puncture, type of puncture, magnitude of applied force, momentum, direction of force; however, it is felt that the mouthpiece tests are representative of the hood material's minimum tear resistance. As such, it is deemed acceptable.

TABLE 2-5
MAN-MACHINE INTERFACE TRADEOFF STUDY

CRITERION	%	Mouthpiece* Rating	x%	Plastic Hood* Rating	x%	Oral Mask** Rating	x%	Oral-Nasal Mask*** Rating	x%	Full Face Mask Rating	x%	Fright Mask Rating	x%
Universal Fit and Seal	20	9	180	7	140	5	100	2	40	5	100	6	120
Dead Space	10	9	90	5	50	8	80	7	70	7	70	7	70
Non-powered communications	30	1	30	9	270	7✓	210	8✓	240	8✓	240	8	240
Weight	5	8	40	9	45	6	30	5	25	1	5	7	35
Bulk	5	9	45	8	40	6	30	5	25	1	5	7	35
Vision	10	7	70	1	10	7	70	7	70	9	90	7	70
Comfort	5	7	35	6	30	6	30	5	25	9	45	8	40
Cost	5	9	45	8	40	5	25	7	35	6	30	4	20
Development Risk for Improvement (high-low)	10	2	20	9	90	4	40	4	40	4	40	3	30
TOTALS (high score wins)	100		385		715		615		560		625		660

* Schjedahl Hood
** Requires noseclip and goggles
*** Requires goggles
(✓) with voice disc

71-1330-T-5

Other test results on the hood are as follows:

1) Lens peel strength (per ASTM-D-903); 2.6 lb/in.

2) Lens haze (per ASTM-D-1003); additional 2.7-percent haze after lamination.

3) Lens luminous transmittance (ASTM-E-308); loss of 3 percent after lamination

4) Mouthpiece flow resistance; 0.75 in. H_2O at 85 SLPM.

5) Neck seal leak integrity; withstands average 1.6 in. water internal pressure without leakage (mated to 4.75-inch-diameter mandrel).

During manned testing of the PBA, it was shown that the hood could be easily donned and doffed without tearing, provides an adequate seal without discomfort, does not interfere with the wearing of a hard hat, and allows good communication. However, light fogging of the lens was experienced after about 20 minutes into the tests. This light fog continued for about 5 minutes and then cleared somewhat by drain-off. Approximately 8 ounces of perspiration collected within the hood during this time. It is felt that use of DeMist antifog on CR-39 lenses as originally planned would alleviate this problem.

Carrying Case Configuration and Materials

The carrying case must protect the PBA from damage before use, it must be hermetically sealed, and it must be easily carried. To supply the greatest degree of utility in emergency situations, the PBA should be nearby the user and, ideally, should be attached to his person.

Originally, plans called for the PBA to be carried on the miner's belt. However, current state-of-the-art limitations on O_2 generation and CO_2 absorption set limitations on weight and bulk which made it apparent that this approach was not really workable for a 60-minute duration apparatus. For the prototype, a shoulder strap arrangement was designed, but it is clear that this approach does not lend itself to continuous carry either.

Several materials, both metals and plastics, were considered candidates for use. The study considered weight, strength (dent resistance), cost, process development, and number of fabrication steps. The combination finally selected is a fiberglass case with a heat-sealed bag around the PBA, resting on foam rubber padding (see figure 2-2). The bag is a hermetically sealed barrier bag notched along the top for easy tear-opening. The sides of the case are slightly bowed to add deflection resistance, and the two halves are joined by a tongue-and-groove joint, secured by quick action snaps.

Fabrication and Assembly

During the design of the PBA, the factors affecting choices in fabrication and assembly were production costs, weight, size, material life, sealing, human engineering, toxicity, and quantity. These all had to be traded off against the overriding considerations of cost and schedule. Therefore, the design effort aimed at achieving sound basic designs and materials that lent themselves to low cost production methods. This rationale applied to each major subassembly, as discussed in the following subparagraphs.

Carbon Dioxide Absorbent Canister

The canister must be light in weight, with good heat transfer characteristics and only minimal structural strength. The canister is described earlier (see figure 2-2). For prototypes, all forming was done manually. The perforated screen is stocked material, and all joining is soldered. Assembly was done manually also, with some spot welding. In production, shapes can be stamped, and assembly can be done by furnace soldering or a similar process.

Shroud

The candle shroud must allow gas circulation around the candle and must be tough, light, and withstand 350°F temperatures at a distance of 1/8 inch. Lexan was chosen, because it has the best combinations of these factors, and it is readily formable. In prototype, the shroud was made in two pieces cemented together. In production, it could be made as one piece.

Breathing Bags

The bags must be lightweight, gas-tight, and able to withstand long-term folding. Nylon, impregnated with polyurethane, was used for the prototype. Seams were cemented. A number of entirely acceptable materials and processes can be used in production, including blow molding and heat sealing.

Chlorate Candle/Case

The compounding and forming of the candle lends itself readily to production techniques. The candle case is fabricated from standard tubing, and all welds to the case can be automated. The procurement specification for the candle required quantity production considerations in the design.

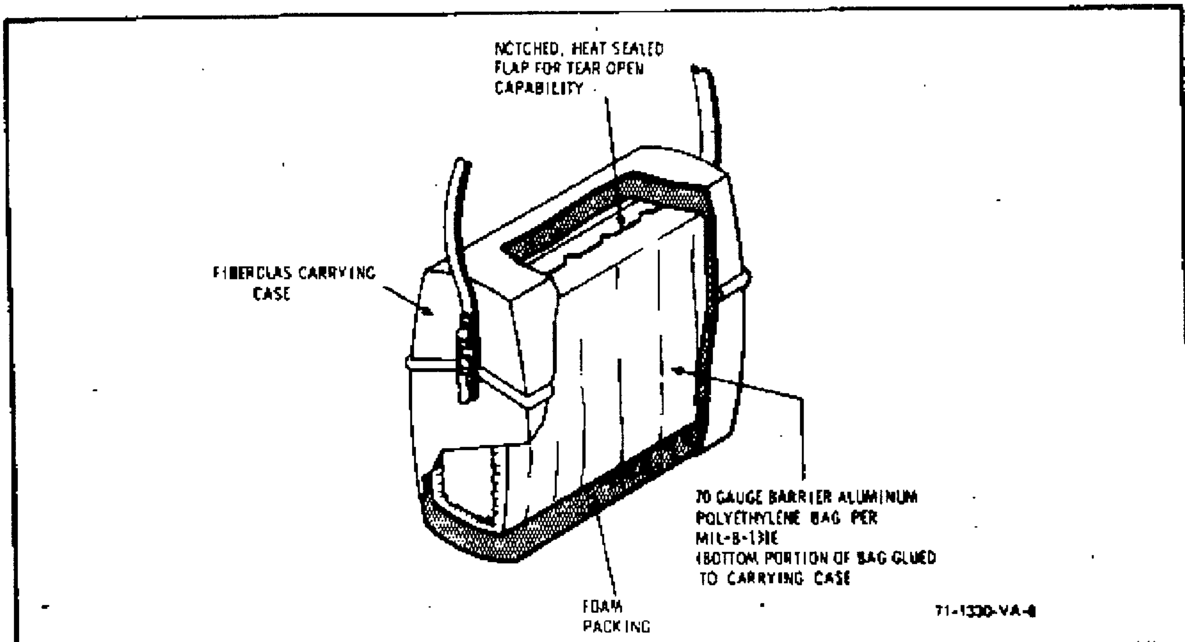

Figure 2-3. PBA Package

Hood

The prototype hoods were also handmade, but the design is very similar to hoods that have been produced in quantity. Therefore, no problems are foreseen in this area.

Accessories

All accessories (filter, hose, clamps, etc) are standard items and present no problems.

PBA Assembly

The joints between breathing bags, hoses, mouthpiece, and canister are cemented (leak tight), tied with wire (strength), and taped (safety). The joint between the breathing bag and the canister, which carries the canister load, is made by bending over tabs on the canister and passing them through grommets on the bags. The canister is secured by hangers riveted to the canister and straps welded to the candle case. The straps are secured to the hangers by self-tapping screws that also hold the shroud. The other end of the shroud is secured by tabs to the canister. The carrying case snaps are secured by heating and compressing lugs provided with the snaps. Table 2-6 lists component weights for the PBA.

As part of the design, a preliminary cost analysis was conducted, based upon production lots of 15,000. The study concluded the $35 to $40 per unit would be possible. It appears that there will be some increase in the hood cost, but the target $50 per unit is still very likely.

AUXILIARY SURVIVAL CHAMBER (ASC)

The following paragraphs contain descriptions and discussions of the selections and decisions made that led to the ASC supplied in prototype to the Bureau of Mines.

Structural Concept

The ASC must withstand hydrostatic or uniformly distributed pressure of from -5 to +20 psi and the end bulkheads must withstand -5 to +20 psi uniform dynamic pressure. It must provide 80 cubic feet of space for each of the 15 men in addition to the 120 cubic feet of space filled with equipment. It must be movable through 3.5x9-foot openings and capable of assembly in areas 6 feet high and 10 feet wide. In movement, the towing load limit is 4,000 pounds per module, and the wheel load limit is 5,000 per module.

Four basic designs were evaluated for the ASC structure. These are shown in figure 2-4. Each is a series of modules latched together to form a closed chamber.

Concept A is composed of five identical corrugated shells braced internally at each end by two compression members and five tension members. Longerons were to be used to transmit longitudinal loads and to provide sealing surfaces and structural continuity. Bulkheads are latched to each end of the assembled chamber.

Concept B is essentially of six flat-bed cars with flat walls and curved roofs. The floor and sides are standard I-beams, channels, and plates.

TABLE 2-6
OVERALL PBA WEIGHT (POUNDS)

Item	Quantity	Actual Weight	Estimated Weight
Canister Assembly	(1)	6.200	--
Body	(1)		0.520
Cooling Fins	(5)		0.416
Exhaust Plenum	(1)		0.018
Exhaust Screen	(1)		0.051
Intake Screen	(1)		0.057
Heat Exchanger	(1)		0.210
Ports	(2)		0.054
End Closure	(1)		0.071
LiOH	--		1.480
Candle and Filter	(1 each)		3.100
Heat Shroud	(1)		0.102
Solder and Shroud Assembly Clips			0.300
Carrying Case	(1)	1.400	--
Carrying Case (Redesign)	(1)		1.437
Straps	(1)		0.060
Man-Apparatus Interface	(1)	0.120	0.120
Breathing Bags and Hoses	(1 set)	0.450	0.400
Carrier Bag	(1)	0.070	0.063
		8.280	8.459

The roof is a single corrugated panel, preloaded with tension ties to the floor. Bulkheads at each end of the shelter are braced by the side walls and by A-frame bracing to the floor.

Concept C is similar to concept A, except that the sheet consists of two pairs of identical corrugated panels; top and bottom are one pair, two sides are the other pair. For height variation, the side panels can be replaced, but this also requires different members for internal bracing. This bracing consists of four compression members and four tension members at each end of the module.

Concept D is a modified concept B. Each module has a volume of 230 cu ft and is a flat-bed car with curved panels that form walls and ceiling like a quonset hut. The floor is I-beams, channels, and plates, with wheels or skids for movement. Two identical corrugated curved panels, hinged along the floor, form the sides and roof. For stowing or movement, the panels are disconnected and folded down onto the floor. To vary height,

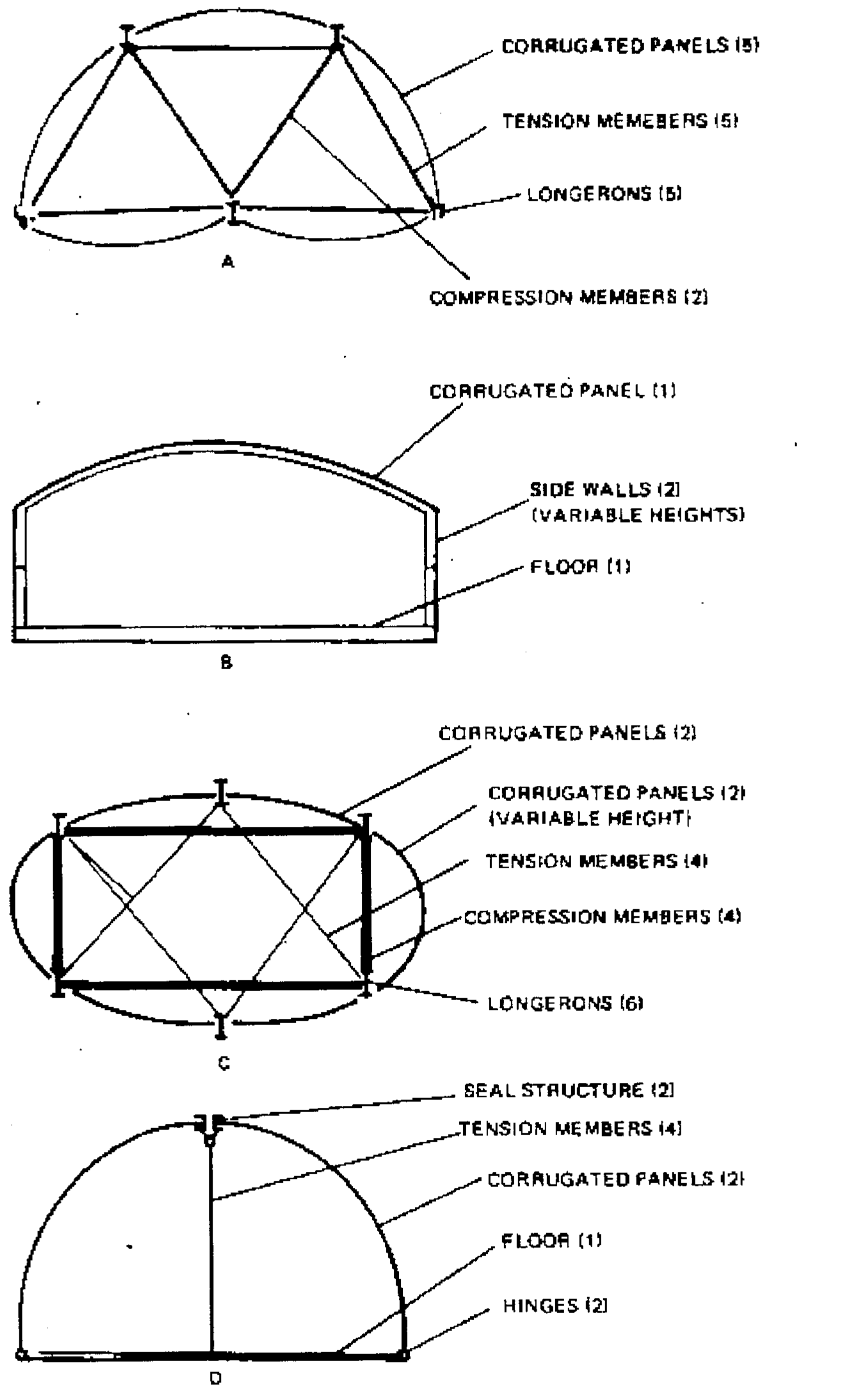

Figure 2-4. Candidate ASC Structures

different panels are used. Bulkheads are attached at each end of the assembled chamber, braced by A-frames either internally or externally. Internal bracing is attached to the floor.

Table 2-7 summarizes the tradeoff study conducted to select the ASC structure. Assembly and disassembly were rated on number of operations and man-hours required. Cost estimates were based upon the assumption that all material was structural steel. Portability was rated by man-hours and other equipment required to move the shelter. As can be seen, concept D was selected. A more complete diagram of this concept is shown in figure 2-5.

The material used is low carbon steel in standard structural shapes. Welding is used extensively to connect structural members. The panels are 6 feet long, with a radius of 53 inches and have an arc of 93.5 degrees. Each panel is reinforced to support the hinges.

The floor is standard I-beams welded to a flat plate, 6x9 feet. The open-beam construction is used as storage space. Axle supports installed at the open ends allow for wheel and axle assembly installation prior to towing operations.

Assembled, the panels are pinned together at the top with four detent pins for an erect height of 68.5 inches. Disassembled, the panels can be folded down onto the floor for low-profile movement.

Bulkheads are flat reinforced corrugated sheet steel and consist of the bulkhead, a platform, and braces. Reinforcing is by rectangular tube beams at four vertical locations. One bulkhead has a hatch that can be sealed from either side and that opens inward for rapid entry. (Production

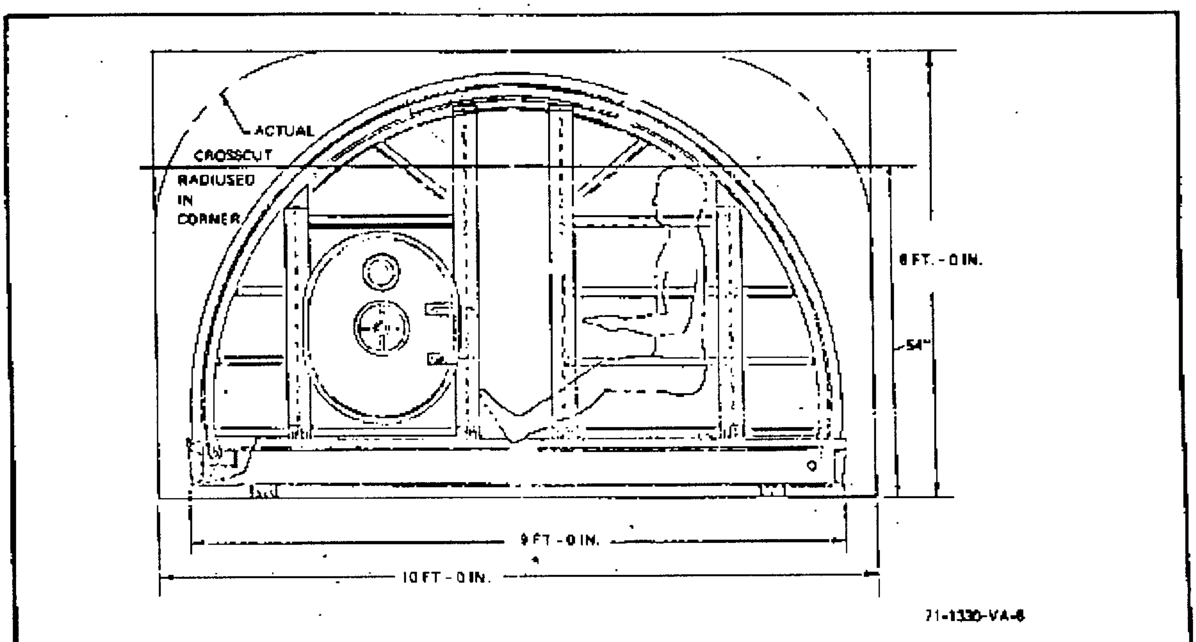

Figure 2-5. Selected ASC Structure

TABLE 2-7
ASC STRUCTURAL CONCEPT TRADEOFF STUDY

	%	A Curved Segment Truss		B Flat Car		C Curved Segment		D Flat Car Mod	
		Rating	X%	Rating	X%	Rating	X%	Rating	X%
Assembly & Disassembly	20	4.40	88	8.30	166	3.20	64	8.55	171
Size Flexibility	7	2.80	20	3.80	27	2.80	20	2.80	20
Cost	20	6.50	130	3.50	70	6.50	130	6.00	120
Portability In Mine	20	2.60	52	5.20	104	2.60	52	5.20	104
Schedule	8	6.30	50	6.50	52	6.30	50	6.90	55
Habitability	5	4.10	21	7.60	38	4.40	22	6.35	32
Sealing Reliability	12	2.60	31	4.20	50	3.10	37	4.60	55
Durability	8	3.60	29	5.80	46	3.00	24	6.50	52
TOTAL	100		421		553		399		609

71-1330-T-9

ASC's would have hatches in each bulkhead.) The bulkheads are shaped to fit the modules and are hinged to the platform. The platform is secured to the mine floor with roof bolts. Braces (3-inch steel tubes) are installed between the platform and bulkhead to provide a closed end and are secured by detent pins. These braces are installed with one end at the top of the vertical bulkhead beams and the other end on the platform, opposite the anchor bolts, so that most pressure loading transmits to the anchor bolts.

Each module, including the bulkhead assemblies, can be towed like a two-wheel cart. Towing lugs are included, and the axle supports accept stud axles and wheels. Equipment is stowed in the modules so that they can be towed fully loaded. With the shells folded down, height is 37 inches, with a nominal 2-inch ground clearance.

Internal Volume Requirements

An integral part of the internal volume requirements for the ASC is the heat created in the chamber over a 14-day period and the chamber ability to handle it. A complete mathematical analysis of heat transfer characteristics of the chamber was performed as a part of the program. Data used in this analysis are as follows:

a. Chlorate candles generate 70 cubic feet of oxygen every four hours and produce 100 Btu of heat per cubic foot of oxygen.

b. Carbon dioxide removal canister produces 1,240 Btu of heat per hour based on 130 Btu/cubic feet of CO_2 absorbed and 10.1 cubic feet of CO_2 produced per hour by 15 men plus 0.9 cubic feet of CO_2 per hour from one CO removal canister.[9]

c. Carbon monoxide removal canister produces 1.19 Btu of heat per cubic foot of CO absorbed.[9]

d. The 15 men at low metabolic rates produce 5,870 Btu of heat per hour.[10]

e. Other equipment in the ASC (light, batteries, communications) generates 100 Btu per hour.

f. Total heat produced from all sources is 8,578 Btu per hour.

Calculations established that, as configured, the ASC can maintain an ambient temperature (of 81° F) if the mine wall has an ambient temperature of 60° F.[12] and an emissivity of 0.88. This does not constitute a stressful environment. If actual metabolic rates or other factors result in higher temperatures, the easiest way to correct this is to add fins to the outer surface of the chamber to aid in radiative and convective heat conduction to the outside.

Kansas State University conducted a series of tests to determine the effect of relative humidity, temperature, and population density conditions upon man's stress limits.[13] The results of tests of these parameters are summarized in table 2-8. In these tests, a 2-degree rise in rectal temperature or illness were used as the measures of stress.

TABLE 2-8
NUMBER OF SUBJECTS EXHIBITING A 2°F-RISE IN RECTAL TEMPERATURE OR SICKNESS IN LESS THAN 8 HOURS

Dry Bulb Temp °F	RH %	ET °F	PACK CONDITION I 8 subjects 36 sq ft/man 288 cu ft/man		II 18 subjects 16 sq ft/man 128 cu ft/man		III 32 subjects 9 sq ft/man 72 cu ft/man		IV 48 subjects 6 sq ft/man 48 cu ft/man	
			+2°F	Sick	+2°F	Sick	+2°F	Sick	+2°F	Sick
95	60	86.8	1	0	0	0	0	0	0	0
95	70	88.8	1	0	0	0	0	0	6	0
98	60	89.1	0	0	2	0	0	0	3	0
95	80	90.8	0	0	1	0	1	0	30	0
98	70	91.3	8	0	3	1	1	1	38	0
95	90	92.9	7	1	6	1	1	2	46	1
98	80	93.5	8	0	17	0	9	0	46	2
98	90	94.5	8	0	18	0	28	4	46	0

Data from reference 13 correlate well with data from other temperature-humidity duration tests in which population density was uncontrolled and which lasted up to 2 weeks.[10] This indicates that numbers of occupants has little effect on temperature and humidity tolerance. In US Navy-conducted tests of a 100-man shelter over a 14-day period, 12 square feet per man was found adequate.[14, 15] Civil defense authorities state that "At least 12.5 square feet and 80 cubic feet per person" are adequate for fallout shelters.[6] Based upon these results and a comprehensive comparison with known survival shelter parameters that have been shown to be livable, the final choice of parameters for the ASC was 84 cubic feet per man, 21.6 square feet per man, 81°F maximum temperature, and 100-percent maximum relative humidity.

Sealing and Reinforcement

The ASC must be airtight and maintain the airtight seals against blasts from -5 to +20 psi. Since the six modules cannot accommodate longitudinal loads of this force, the brunt of the force is absorbed by the bulkheads. Each bulkhead is anchored to the floor with 12 standard roof bolts, driven at 45-degree angles as shown in figure 2-6. In this way, the bolts can carry the load for either horizontal or vertical pressure and can overcome moments of force in both directions resulting from positive or negative pressure.

A variety of concepts was explored for sealing the ASC, including compressed rubber strips, zippers, inflatable seals, permanent adhesive, and rubber seals with "Pull-a-Dot" fasteners. The last two of these were selected to seal the 283 feet of seal required (see figure 2-6).

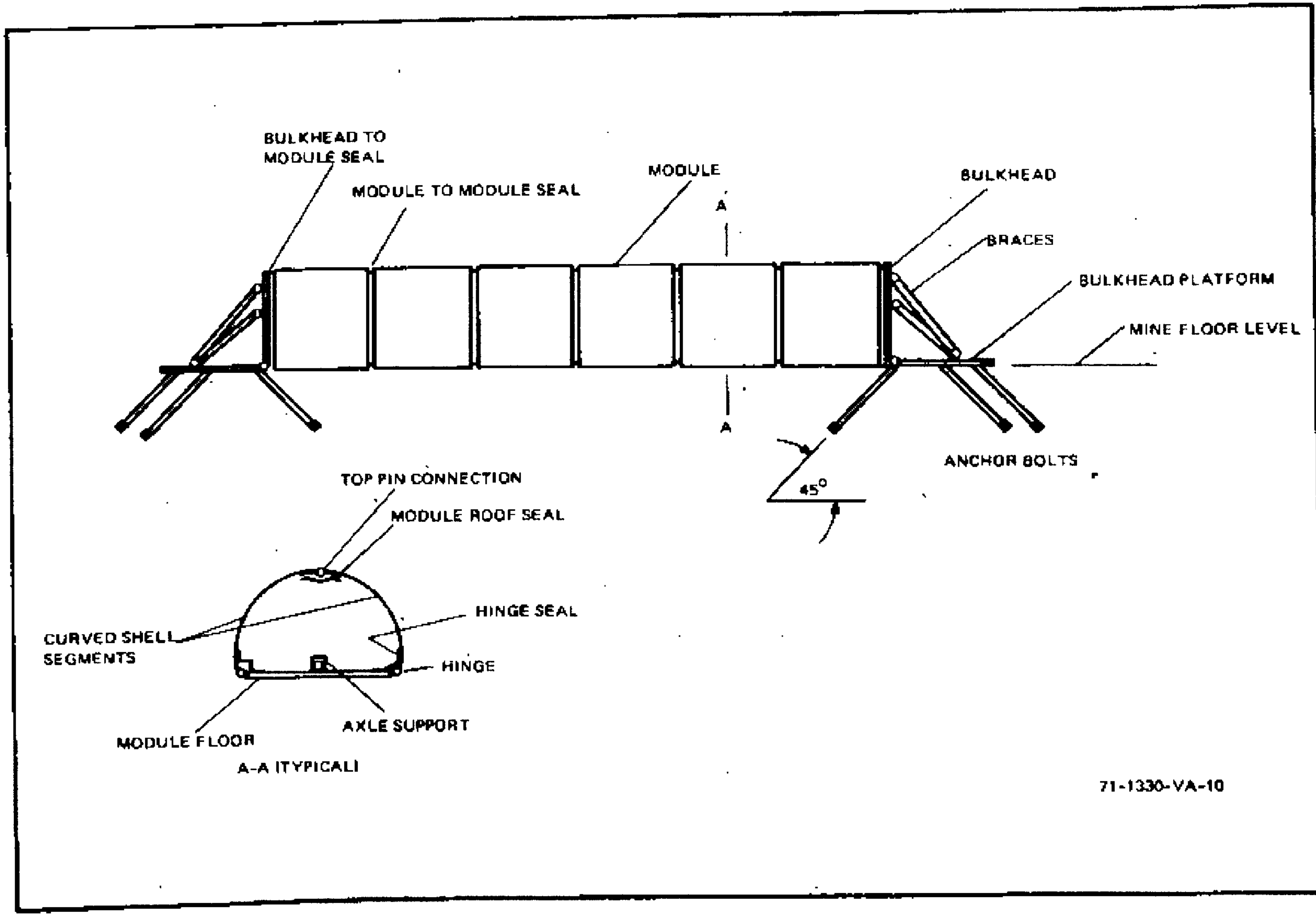

Figure 2-6. Assembled ASC

Seals are secured by permanent adhesive, or Pull-a-Dot fasteners, or both. Permanent adhesive is used in hinge areas where seals are not removed in disassembly. The seals are bonded to the floor and to the shell segments, becoming permanent parts of the module. The Pull-a-Dot fasteners are used where seals are removed in disassembly, for example, in the roof and module-to-module joints. Engaging the snaps with permanently installed mating parts compresses the rubber seal. The fasteners can be oriented so that they can be opened from both inside and outside the chamber.

Module roof joints are about 5 inches wide, with 6-inch gaps at each end. The gaps are temporarily sealed with tape before installing the seals. The seal used to seal the gap is shaped like a race track, providing a continuous seal all around the opening. Continuous seals are also used between modules. The fasteners are secured to each module, and excess material between the inner rows of fasteners is provided to accommodate gapping. Nominal gap is 1 inch; the seal permits 1.5 inches. The fabric connecting the seals is cut on a bias to allow for vertical and side mismatch up to 0.5 inch.

Bulkhead-to-module seals use a combination of snaps and adhesive. One edge of the seal is bonded to the bulkhead and secured with retaining plates. The other edge is held by the Pull-a-Dot fasteners when the bulkhead is joined to the module. The hatch seal is a soft rubber strip built into the hatch that compresses when the hatch is closed.

In the axle support area, a wing nut is tightened against a bearing plate that is supported by the inner axle lug. A rubber lined seal plate is then screwed tight over the opening, compressing the rubber to form the seal. Another soft rubber strip is secured to the outer edge of each module hinge so that it is compressed when the shell section is erected so as to protect the inner hinge seal against overloading when exposed to sudden high pressures.

<u>Atmosphere Conditioning Unit (ACU)</u>

Two atmosphere conditioning units are included in each ASC to produce oxygen, remove carbon dioxide, remove carbon monoxide, and circulate internal air. The ACU also prevents inward leakage of poisonous gases by maintaining a slight positive pressure in the chamber by drawing in some outside air through leakage control hoses.

The design parameters for the ACU are listed below:

a. Inlet CO concentration of 1,000 ppm; outlet less than 50 ppm
b. Inlet CO_2 concentration of 1 percent; outlet less than 0.1 percent
c. Inlet air flow of 15 SCFM or more
d. Inlet humidity of 80 percent
e. Inlet temperature of 50 to 80°F; outlet less than 100°F
f. Control of seal leakage
g. Manually operated and easy to assemble
h. Built-in-breathing (BIB) system with mask outlets for 8 men each.

Oxygen Supply

The objectives of the oxygen supply were capacity for 210 man-days, easy assembly, low-cost, portability, minimum development time, and high safety and reliability. There are four basic practical methods of supplying oxygen in this kind of application: high pressure storage, cryogenic storage, electrolysis of water, and chemical reactions that give off oxygen (ref. 5, 9, 11, and 16).

Cryogenic methods were rejected on the basis of cost. Electrolytic methods were not safe enough for the ASC. High pressure storage does not afford enough portability, reliability, or safety.

Among chemical reactions, potassium superoxide and sodium chlorate were considered most applicable. Potassium superoxide was eliminated on the basis of inordinate development time required. Therefore, the ACU uses chlorate candles to produce oxygen. Each of the candles used produces 70 cubic feet of oxygen. Seventy (70) candles will be required based on normal oxygen consumption rate of 1.78 pounds per man-day for 210 man-days, plus 46 pounds of oxidation of CO. Assuming the worst case for the surrounding atmosphere (no oxygen in the mine) 14 more candles would be required. The candles are connected to the ACU so that if the built-in-breathing manifold is in use, oxygen in the system is increased by 10 percent.

Carbon Dioxide Removal

The ACU must remove 90 percent of the CO_2 produced by 15 men, and each unit must be capable of accomplishing this alone, in case one unit breaks down. The same general design objectives apply here as applied for the oxygen supply. The three most likely candidate methods of removing the CO_2 are chemical absorption, cryogenic condensation, and osmotic diffusion (ref. 5, 9, 14, 16, 17, 18). All will handle the CO_2 generated by 15 men.

Cryogenic condensation and osmotic diffusion were rejected on cost, safety, and portability. Chemical reactions considered were potassium superoxide, baralyme sodasorb, and lithium hydroxide. Potassium superoxide was rejected on the basis of cost and development required. Sodasorb shows too much dusting, too much corrosion risk, high cost, and low efficiency. Baralyme and lithium hydroxide were very close candidates, with baralyme holding small advantage in assembly-disassembly time, cost, schedule, and safety.

The baralyme canister is a vertical axial-flow refillable type with lateral baffles. The axial-flow type was chosen to preclude the possibility of channeling in the canister. The size of each canister was based on available storage space, manual handling considerations, and an 8-hour duration. The rate of CO_2 removal was based on generation of 1.26 pounds of CO_2 per hour from 15 men, 0.12 pounds from the carbon monoxide-removal canister, and 0.1 pound drawn in through leakage hoses (outside concentration assumed to be 10 percent). For the 14-day mission, 42 canisters are supplied with each ACU.

Carbon Monoxide Removal

An extensive literature study and a design, test, and development program formed the background for the CO removal canister supplied with the atmosphere conditioning units for the ASC.

Carbon monoxide can be removed from an air stream by absorption or by catalytic reaction. Catalytic reaction, using Hopcalite as the catalyst, performs acceptably and within the operating requirements. Hopcalite is a coprecipitated mixture of manganese dioxide and cupric oxide, with small amounts of cobalt and silver oxides, and it can catalyze CO oxidation at mine temperatures.

Hopcalite is attacked by water vapor at temperatures below 250°F and can be poisoned by traces of antimony.[9] Below 350°F, Hopcalite may absorb unsaturated hydrocarbons, which may ignite if hydrogen is also present.[19] In other applications, no standard design existed for this use of Hopcalite; therefore, a new filter-bed design was required. All traces of water vapor and antimony were eliminated from materials, finishes, and assembly of the canister, and provisions were included to remove water vapor during operation.

The canister housing was designed to 6-3/4 x 9 x 13-inch dimensions of zinc-plated sheet steel. Seams are spot welded and soldered; points of wear are reinforced; and the spring-loaded filter bed is held by two metal screens. A wall baffle is included to prevent channeling. The filter bed originally consisted of a 1-1/2 inch layer of activated charcoal, a 5-1/2 inch layer of silica gel, a 1-1/2 inch layer of molecular sieve, a 1-inch layer of Hopcalite, and metal screens top and bottom. Flow is axially downward. The charcoal layer was intended to absorb unsaturated hydrocarbons, but since neither these compounds nor hydrogen will be present in quantity, the charcoal layer was eliminated. The silica gel and molecular sieve absorb water vapor at high and low humidities, respectively. When they saturate, the water vapor attacks the Hopcalite, and the CO at the outlet increases.

When the charcoal layer was removed, the Hopcalite layer was increased to 2-1/2 inches, and a baffle plate was added at the outlet to distribute flow. In testing of this configuration, breakthrough (start of increase in CO at outlet) did not occur until 6 hours of operation had elapsed under design conditions.

The effects of chamber seal leakage resulted in a 3/8-inch leakage control hose being added between the chamber wall and the carbon monoxide canister. With the chamber seals installed, the hoses provide lower leakage resistance than the seals; so the inward flow of mine gas is immediately scrubbed. When the ACU's are operating, the hoses draw in mine air to maintain a slight internal positive pressure and seal leakage occurs in the outward direction only. Under normal conditions, considering leakage, activity levels, and other sources of contaminants, the ACU's require about 51 minutes operation per hour to maintain both CO_2 and CO below maximum limits. Because CO in a mine decreases with time after a blast, a design duration of 5 days was considered adequate. Therefore 28 CO removal canisters are supplied.

Built-In-Breathing Manifold

For emergencies, a built-in-breathing (BIB) manifold is included in each ACU. In operation, the manifold is connected directly to the ACU outlet so that the air supplied contains an additional 10 percent of oxygen. Each ACU manifold feeds eight hoses and facemasks.

Ventilation Components

All ducts, hoses, manifolds, and facemasks are fire resistant, easy to attach or repair, and spaced to avoid crossing. The blower hose is disconnected from the manifold and used as a ventilation duct to the chamber when not in the BIB mode. The blower is a hand-cranked gear-driven centrifugal bomb shelter ventilator, and it can be operated at 40 rpm for about 30 minutes by one man using one arm.

Furnishings

Personal necessity items required in the ASC are minimal; bunks, blankets,and personal hygiene kit. Double bunks are used to conserve space. Blankets are fireproof "Nomex". The hygiene kit is primarily used to ensure cleanliness in treating wounds.

To overcome the stress of forced inactivity, Bibles, pencils and paper, playing cards, and some games are supplied. Radio broadcasts may also be piped in through the Communications Subsystem equipment.

Fire extinguishers, first aid equipment, and tools are also provided. A water-type extinguisher is supplied in the chamber for wood and paper fires; a chemical extinguisher is supplied outside for electrical fires. First aid equipment is a standard miner's kit, to which have been added aspirin, a cleansing agent, tincture of merthiolate, a resuscitube, and a Foille burn kit. A collapsible stretcher is provided outside the chamber, and the bunks can also be used as stretchers. Inside the chamber, a standard tool kit consisting of pliers, wrenches, hammer, saw, and nails is supplied for repairs. Outside, shovels, axes, and other heavy tools are supplied, along with six PBA units.

Electrical System

The electrical system for the ASC was originally going to be a 24-volt off-the-shelf permissible system, but lack of availability of acceptable equipment led to the choice to design a system for intrinsic safety. System voltage was dropped to 12 volts, and current-limiting resistors were added to the circuit to hold energy levels under 100 millijoules per branch (see figure 2-7). Each load branch is also fused and switched. Battery and control circuits are integrated in one box.

In this system all components work at less than 50 percent of their ratings. The battery is a 12-volt 96-ampere-hour-per-charge zinc-air unit that is mechanically recharged. Eight recharge kits are supplied for a total of 768 ampere-hours. Oxygen required for this battery system will not exceed one cubic foot per day. The lamps used are 4-volt units, used two in series in each of three lines (lines 1, 2, and 3 of figure 2-7). Using one line 24 hours, one line 16 hours, and one line 8 hours per day requires recharging every 48 hours, depending upon how much power is supplied to the communications equipment (line 4). Line 4 can be used to power the communications directly, or it can be used to direct power from the communications battery to the lights. All jacks and lamps are color coded.

A back-up lighting system is provided. Cyalume panels, a chemical-emitting light source, will provide 224 hours of low level illumination.

This system complies with reference 5 (schedule 2G); it is simple to operate; it uses low-cost off-the-shelf components; and it requires almost no maintenance.

Food and Water

Food was selected for nutrition, shelf life, packaging, cost, and availability. Several candidates (dehydrated, pemmican camping goods, Pillsbury's "Space Stick") were considered, but the standard proven military ration (MIL-F-43231, Food Packet, Survival, General Purpose) was chosen as most applicable. Each packet contains about 870 calories, and 2 per man per day are supplied to give each man 1740 calories per day.

The water supply is twenty (20) 5-1/4 gallon plastic containers that fit readily into the ASC and can be used for waste disposal when they are

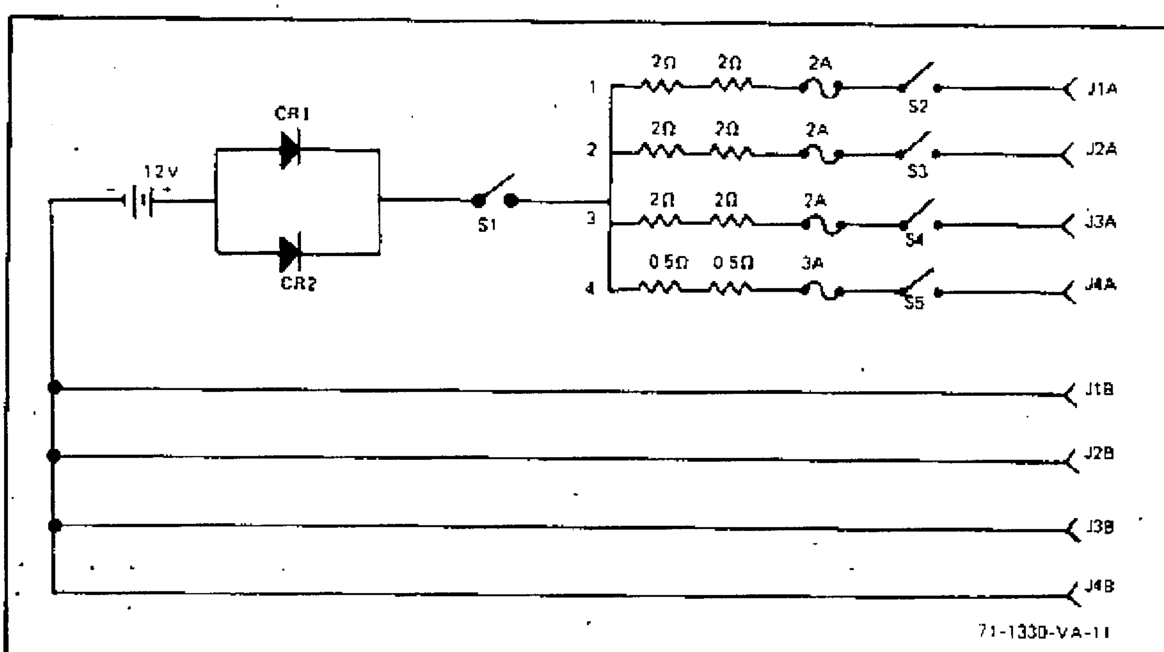

Figure 2-7. ASC Electrical System

empty. The water is regular tap water with 1 teaspoon of chlorox per container added to assure long storage life in the absence of significant sunlight exposure.

Waste Disposal

For simplicity, low cost, and reliability, the Stello Products portable toilet is used. Ordinary Listerine[12] mouthwash can be used as the bacteriostat and deodorant. The disposable bags are double-sealed plastic, and they may be thrown out the hatch if the outside atmosphere will permit.

Fabrication and Assembly

The design of the ASC was directed toward ease of fabrication with methods available in a common welding shop. The material used is low carbon steel, and all welding was done to Specification AWS D1.0-6.9. The three sections of the module; floor, right panel, and left panel, were fabricated in parallel and joined together.

The floor of each module is 6x9 feet and is fabricated of standard I-beam and channels welded to a flat plate.

The side panels are standard low carbon corrugated steel curved on a radius of 53 inches and subtending an arc of 93.5 degrees. Off-the-shelf panels could not meet the arc requirements; so the panels are fabricated from two smaller sections, welded lengthwise at mid-height. They are then bent to the proper curvature in the welding shop. The panels are connected to the floor with hinges and pins. The hinges were welded with the round bar in place, which provided near perfect alignment.

Bulkheads are flat corrugated sheet steel, reinforced by four rectangular tube beams. The bulkhead platform is a standard rectangular tube beam welded to a flat steel plate.

Seals were fitted by a cut-and-try method, which was time consuming but not difficult. Templates were used to locate and install the Pull-a-Dot fasteners.

Final assembly of the life support center, outfitting and power supply systems in the chamber is a straightforward process, requiring no special skills and creating no significant problems. As the equipment is laid out, shock cords are installed to hold movable items in place. Materials and assembly of ACU components were noted in the functional descriptions. Particular care was exercised in their fabrication and assembly to prevent contamination from any source.

LARGE CENTRAL CHAMBER (LCC)

No large central chamber has been built to date. The Coal Mine Rescue and Survival System contract required a comprehensive and workable design and layout for the LCC but no hardware. The procedures followed to fulfill this requirement were the same as required to design and build an actual chamber. The following paragraphs discuss these processes.

Structural Concept

The function of the LCC is to protect up to 50 trapped miners for as long as 14 days, while rescue operations attempt to free them. The LCC

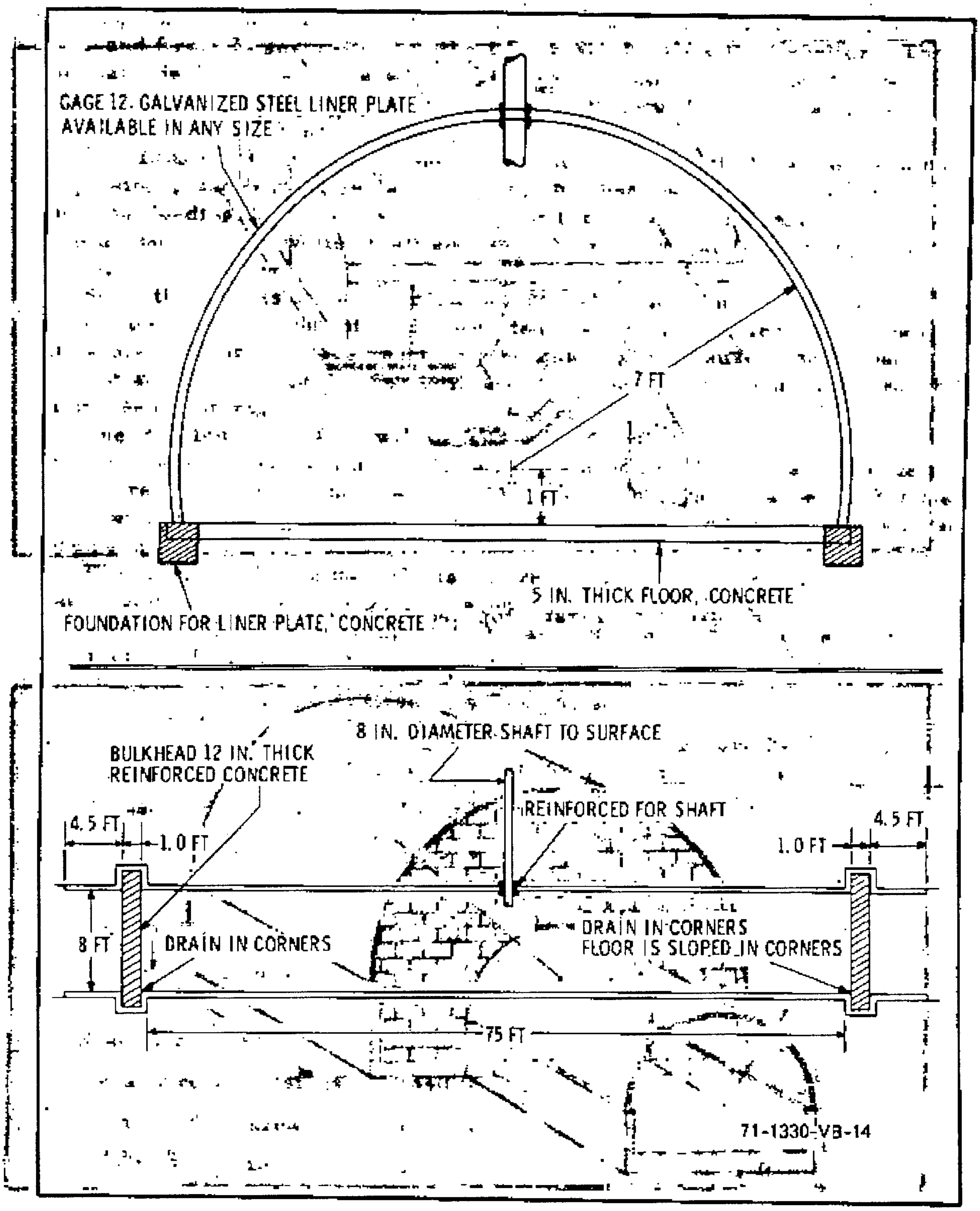

Figure 2-10. Selected LCC Configuration

Structural efficiency is determined by how strong a structure must be to carry a given load. In this area, an arch shape is most efficient, and the shorter the space, the lighter the structure can be.

The selection of floor space and volume for the LCC was based on the same considerations as for the ASC (see refs. 6 and 10-15 and section on Structural Concept for Auxiliary Survival Chamber). The selected configuration gives each of the 50 occupants 137 cubic feet of space which is greater than that allotted in the ASC but recommended because of larger number of occupants.

A basic cost analysis shows the configuration in figure 2-10 to be least expensive, because the arch span is less (thickness of material less) and because no end walls are required (as in figure 2-9).

Excavation costs will be less if coal is excavated for the construction and more if waste material has to be excavated. Therefore, structure shape should be tailored so that waste excavation is held to a minimum. The selected concept accomplishes this.

Heat transfer characteristics are a significant consideration to life support and are discussed in some detail later. Ventilation is also extremely important, and it, too, is discussed in detail under the next paragraph heading. However, in both cases, the basic structural concept selected (figure 2-10) performs well.

Several construction materials were considered for the LCC. Wood was summarily rejected. Brick was rejected on the basis of cost and insufficient strength to carry the required loads. Pre-stressed concrete was rejected, because it is prefabricated, and the components would be much too large and heavy to handle. From a cost and simplicity viewpoint, cement blocks would be best, but they are not strong enough to support the required loads. They are now used as stoppings, and blasts usually blow them out. All metals except steel were rejected on the basis of cost.

In the program proposal,[4] reinforced concrete was specified for the LCC. Sand, aggregate, cement, and reinforcing steel can be carried into the mine easily. The steel can be wired into place, the forms built, the concrete electrically mixed and pumped into place[20, 21]. However, during an investigation of tunnel construction techniques,[22, 23] a better material was found for parts of the chamber; it is called liner plate.[24]

Liner plate is corrugated curved steel plate that comes in 18x50-inch sections that weigh about 37 pounds each. It is already in use in mines in sloping entries to provide ample width to accommodate track, walkway, air ducts, electrical conduits, and belt conveyors. Semicircular liners are also used as underground vaults. Circular liners are used as vertical entries and shafts (see reference 25 for further details on liner plate).

The structure made with liner plate will use reinforced concrete for both the floor and blast walls. Only the ceiling and side walls will use liner plate. Some of the advantages of liner plate over other materials are listed below.

a. Better heat transfer
   1. Steel has high thermal conductivity
   2. Surface area increased 12 percent by corrugations
   3. Adaptable to adding fins, if required
b. Easy construction
   1. Lightweight, easy to handle
   2. No special tools
   3. All bolting from inside (designed that way)
   4. No forms or temporary supports needed
c. Liner plate can be removed from the inside, allowing miners to construct a tunnel from the chamber if needed for escape
d. Liner plate is available to make tunnels that are within 2 inches of any desired rise of span (more than 4, less than 30 feet).

Based upon the 1,000 psi loading and a safety factor of at least 2, calculations indicated that Gage 12 Armco liner plate should be used. It should be galvanized and painted with a high integrity paint for corrosion control. It must be back grouted after installation to develop buckling resistance.

The blast walls should use 3,000 psi concrete with 40,000 psi yield no. 7 steel reinforcing bars at 10-inch spacing. General blast wall design follows references 20 and 21. The shape of the blast walls is shown in figure 2-10. They will be 12 inches thick and will be supported by the beams that support the doors and by the side of the tunnel. Figure 2-11 shows one wall with two doors, the other wall with one.

Commercially available ships doors can be used for all three doors. The door frames are 3x2x5/16-inch angles that come with the doors. A subframe of 36,000 psi yield steel will be required. A wide flange I-beam (12WF22) has a section modulus of 25.3 cubic inches and should therefore be used for the subframe. This will carry the load of 700 pounds per inch from the door and concrete wall.

The door frames can be welded to the subframe and then carried into the mine. The unit shown in figure 2-11 weighs about 1,100 pounds.

There should be one small quick-acting door in each bulkhead. The size of these doors is 24x30 inches, with 8-inch radius corners. These are the doors to be used by the miners in case of emergency. Being small and quick acting, they will restrict the amount of contamination that enters during use. The other door is 36x60 inches with 8-inch radius corners. It is not quick acting and should be used only during construction to carry equipment and supplies into the chamber.

The floor will be plain 3,000 psi concrete, reinforced only for temperature and shrinkage. It will be 5 inches thick with number 3 steel bars on 10-inch centers in both directions. It will slope 1 inch per 7 feet from the center to the corners for drainage.

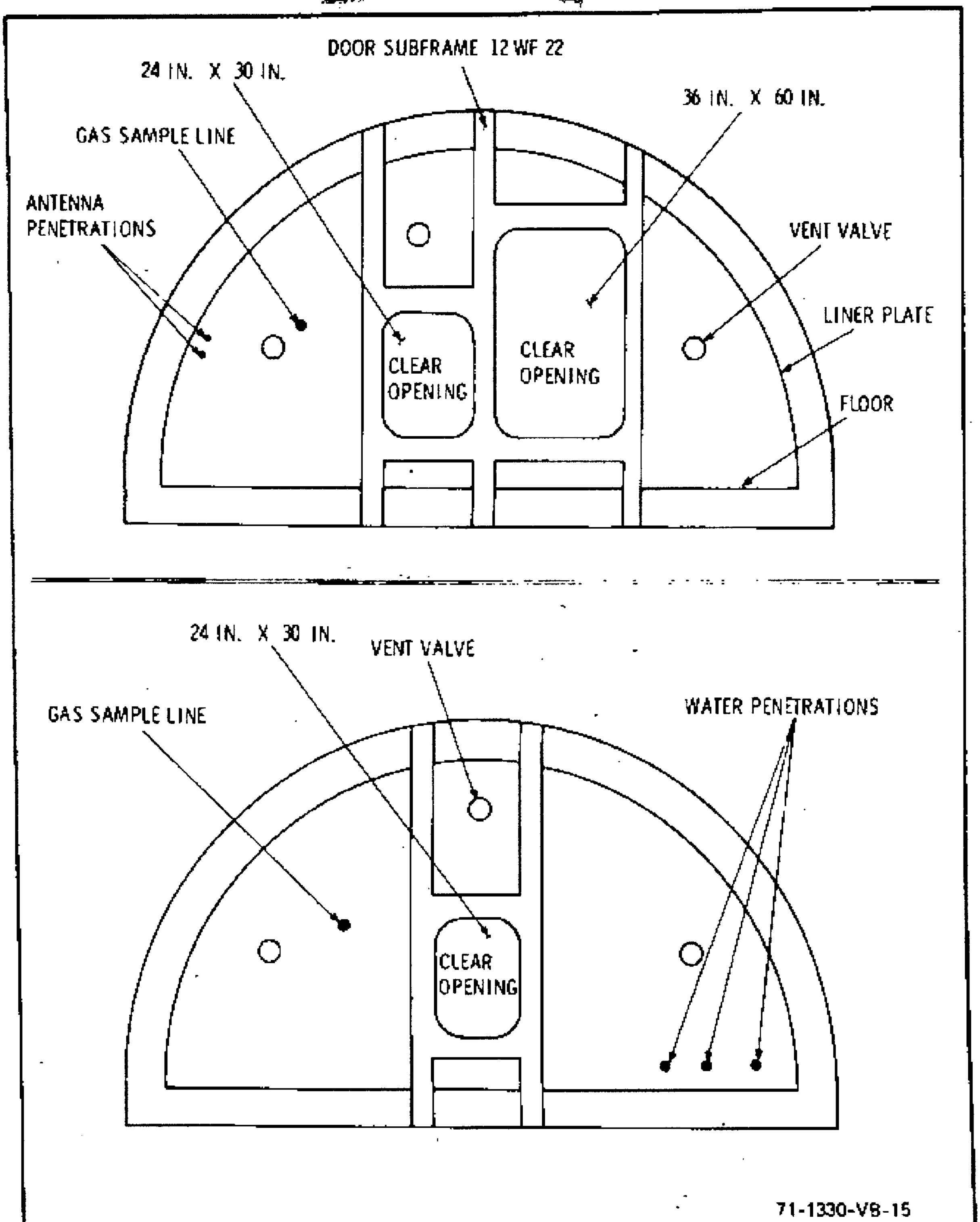

Figure 2-11. LCC Structure and Dimensions

The footings for the liner plate will be plain 3,000 psi concrete, reinforced for temperature and shrinkage with number 3 steel bars on 5-1/2-inch centers. The ground is assumed to be capable of carrying 6 tons per square foot loading. To accommodate the loading (7,000 pounds per foot) and the safety factor, the footings should be 10 inches thick and 12.6 inches wide.

The crosscut leading to the LCC is also reinforced to keep the areas around the doors free of rubble. It is reinforced for 4.5 feet in each direction with the same materials as used in the main chamber (liner plate roof and side walls, concrete floor, and footings).

The liner plate has one penetration; the 8-inch shaft to the surface. The liner plate is reinforced with a 10-inch pipe welded to the plate at this opening. The floor has four penetrations; water drains in each corner. These are 1-inch galvanized iron pipe with hexagon head plugs that are removed to drain the water. Each bulkhead has three 8-inch pipes used as ventilation valves. One bulkhead also has three 26-inch sections of 1-1/4-inch galvanized iron pipe for water (two for supply, one drain). Each bulkhead will also hold 1/8-inch iron pipe for gas sampling. One bulkhead will also hold the communications antenna (two 1/2-inch penetrations).

Excavation of the site for the LCC will, of course, depend upon the specific requirements of the particular mine. Standard mining techniques can be used, such as undercutting, drilling, and blasting or a continuous miner can be used to cut rectangular shapes as shown in figure 2-12, wherein the shaded area can be grouted for support. Blasting can also be

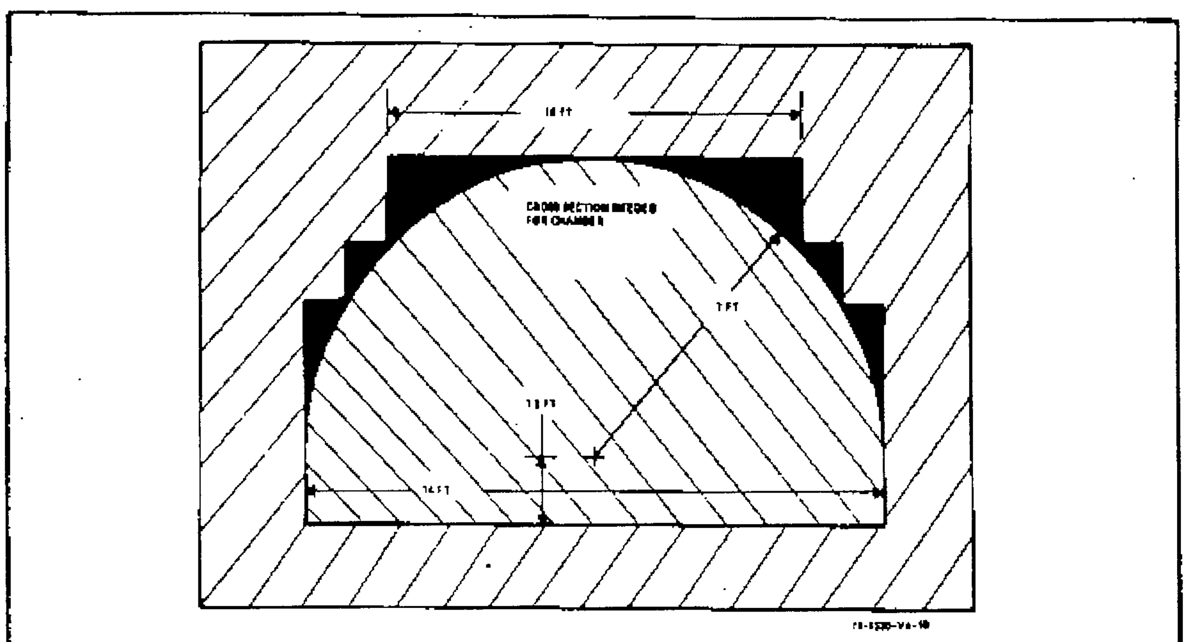

Figure 2-12. Required Excavation

used after the continuous miner to obtain the required shape. The cost of grouting could increase the LCC cost by as much as $840.

Ventilation and Heat Transfer

Ventilation and heat transfer for the LCC must be considered in two phases; with surface ventilation equipment in operation and without. Basic design parameters under consideration are listed in tables 2-9 and 2-10. Analysis showed that if surface air and cooling were cut off, and no emergency ventilating mode was provided, temperatures could rise above survivable levels.

The actual analysis of the thermal characteristics is included as Appendix A to this volume. The analysis is written so that mine owners can review the parameters given in tables 2-7 and 2-8 and then substitute values that correspond to his mine conditions to arrive at an ideal system for his application.

Metabolic heat loss used was 400 Btu/hr[11]. The range for the LCC is from sleeping (280 Btu/hr) to cranking (860 Btu/hr). Actual tests have shown a mean metabolic rate of 485 Btu/hr.[26] The activity in the LCC is much less than in the tests described; so, 400 Btu/hr appears a reasonable figure.

The selection of the design limit on effective temperature was critical. The Office of Civil Defense[11], describes an effective temperature of 85°F as causing casualties in men of middle-age. Tests at Kansas State University[13] indicate that a dry bulb temperature of 85°F and an 80-percent relative humidity did not cause undue stress. The limits set were 84°F and 100-percent relative humidity.

For the analysis, the typical mine was assumed to have a 5-foot coal seam, with the balance of the strata being shale (see reference 27, table 5), because 50 percent of coal mined in 1965 was mined from seams less than 5 feet thick.

Several approaches were considered for temperature control within a chamber which is isolated from the surface, including enlarging the surface area, adding fins, using heat pipes, and water cooling.[28, 29]. Ground rules stated that power and water lines to the surface might be damaged; so, they could not be relied upon for cooling.

Enlarging the surface area was rejected because of the large volume it would require in the chamber. Fins were rejected because of the excessively large area of fins required. Heat pipes were rejected because of degradation of the vacuum system required, because heat pipes have not been used in this type of application, and because of cost.

A schematic of the two-part system selected is shown in figure 2-13. The two basic parts of the system are the surface equipment and the equipment in the chamber. The surface equipment consists of an air-cooling unit and thermostat (for summer use), a compressor and a duct air heater and thermostat (for winter use), and an 8-inch ventilating shaft with a hatch.

TABLE 2-9
LARGE CHAMBER ATMOSPHERE CONDITIONING SYSTEM

			50 Men, 14 Days Total Stay	
			Normal Operation	Emergency (without shaft or elec)
Oxygen	Supply Rate (1.5 lb/man day)		3.125 lb/hr 0.633 CFM at NTP	3.125 lb/hr 0.633 CFM at NTP
	Total, In 15 Days		1,050 lbs	1,050 lbs
	Fract'n % O_2 p O_2, mm Hg		18 - 21 137 - 160	18 - 26.3 (1) 137 - 200
CO_2 (R Q =.85)	Generation Rate	Wt	3.66 lb/hr	3.66 lb/hr
		Vol	0.539 CFM at NTP	0.539 at NTP
	Frac'n, % CO_2		0.25 - 1.00	0.25 - 1.50
Trace Contam	CO, ppm CH_4, % Vol		0 - 25 0 - 1.5	0 - 200 (2) 0 - 3.5 (3)
Chamber Air	TEMP	Design Limit	82°F 55° - 84°F	82°F 52° - 84°F
	R. H.	Design Limit	50% 35 - 75%	100% 50 - 100%
Metabolic	H_2O lb/man-hr Heat BTU/hr x man		0.13, Design; 0.05 - 0.20, Range 400, Design; 280 - 800, Range	

(1) Fire risk limit

(2) 24 hr limit, NAVSHIPS 0900-028-2010

(3) Proximity to explosive limit

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TABLE 2-10

LARGE CHAMBER ENVIRONMENTAL AND SIZE CONSTRAINTS

SURFACE AIR		DESIGN	RANGE
Dry Bulb Temp	F	90	15 - 105
Rel. Humidity	%	70	20 - 90
Humidity Ratio	lb/lb	0.0218	
Rock Strain at Depth			
Temp	°F	60	50 - 75
Spec. Ht. (All Strata) C_1	$\frac{\text{HrBtu}}{\text{ft x °F}}$	0.2	
Conductivity, k, Btu/Hr x ft x °F			
Coal		0.15	
Shale		0.80	0.60 - 1.5
Density, ρ lb/ft^3			
Coal		82.5	
Shale		165	155 - 190
Diffusivity, $\alpha = \frac{k}{\rho c}$ Btu/lb x °F			
Coal		0.0091	
Shale		0.0242	
Transmission Coeff. U $\frac{\text{Btu}}{\text{Hr x ft}^2 \text{x °F}}$			
Air to Metal (Ref 3. p. 58)		0.77	
Grouting (=1/2 Gypsum Brd Seven & Fellows, 11.8)		0.38	0.3 - 0.55

Chamber Size = 75 ft x 14 ft x 8 ft High

Volume = 6,850 ft^3 (137 ft^3/Man)

Total Surf. Area = 3,054 ft^2 (61 ft^2/Man)

Floor = 1,043 ft^2 (20.9 ft^2/Man)

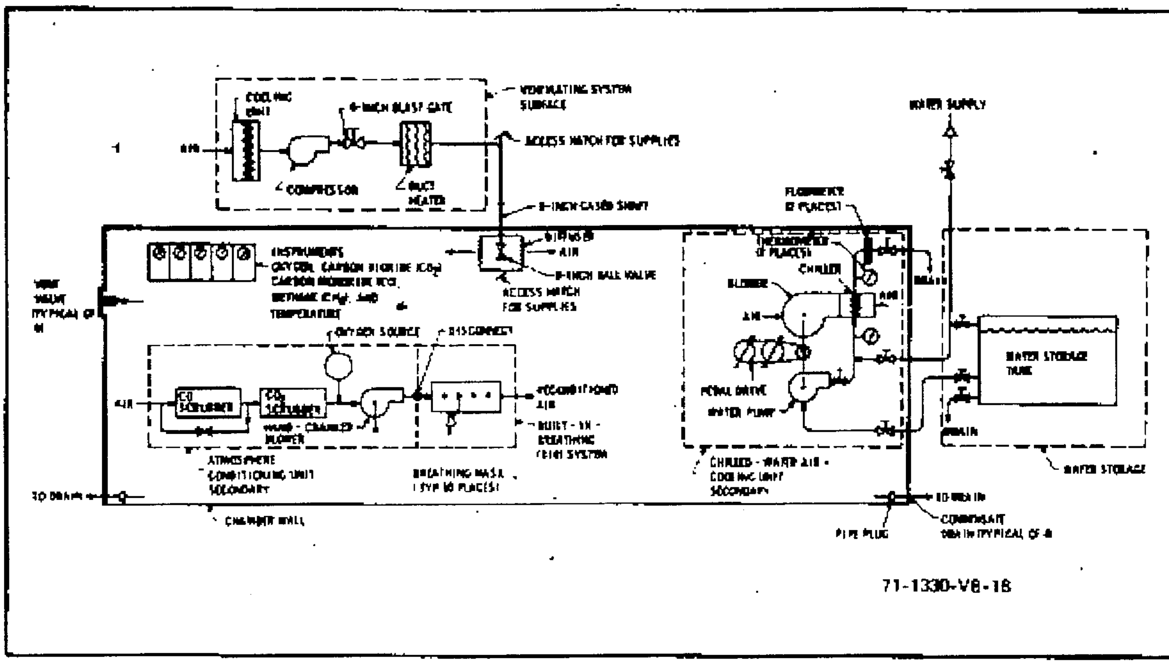

Figure 2-13. LCC Atmosphere Control System

The shaft is fully cased for maximum protection. In normal operation, the compressor (standard off-the-shelf) drives 800 cfm of cooled or heated air through the shaft into the LCC. When pressure in the LCC exceeds 2 inches of water, one-way valves in the bulkheads open to exhaust the air. This minimum internal pressure helps assure no leakage from outside. The valve release also allows carbon dioxide and carbon monoxide to be purged by the normal circulation of fresh air. The cooling unit is a standard commercially available 8-ton chiller (evaporator, compressor, condenser), and it is thermostatically controlled. The heater is a standard 6-kW electric unit, and it is also thermostatically controlled. A diffuser is located in the chamber to circulate the air.

The emergency equipment in the chamber will not be used unless the shaft is closed by explosion or the surface equipment is inoperative for any reason. Water for air cooling is supplied from a tank just outside the chamber. Water at 60°F is supplied to a heat exchanger and blower: the pump and blower are driven by two men on a bicycle-type drive arrangement.[30] Five atmosphere control units, like the ones supplied in the Auxiliary Survival Chamber, are supplied for the LCC. The only difference in the units is that the LCC units have built-in-breathing manifolds with 10 output hoses and facemasks. They operate in exactly the same way, generating oxygen from chlorate candles, scrubbing carbon dioxide with baralyme, and scrubbing carbon monoxide with Hopcalite. These units are also hand-cranked. Supplies of the emergency system are adequate for 5 days of operation. It is assumed that this will be enough time to drill another shaft or reopen the original.

Electrical System

The design of the electrical system for the LCC is the same basic battery box circuit used in the ASC (see figure 2-7). Two of these units are included in each chamber. Enough recharge kits are supplied in the LCC for 1,536 ampere-hours of normal operation. Lamps for the LCC are standard miner's cap lamps (without external batteries). Two lamps are used in series with a current-limiting resistor in each of six branches (two circuits). Lighting schedule is the same as for the ASC and it will require recharging batteries every 48 hours, depending upon the power requirements for communications. A back-up lighting system of the same cyalume lights (ASC) is supplied for up to 448 hours of low-level illumination.

For two-way communications, a MIL-T-15514, Type H203/U Sound Powered Telephone is used. It will transmit for distances well in excess of the deepest mine, and requires almost no maintenance. The only disadvantage is that there should be continued monitoring at both ends.

The high-voltage wiring for the surface equipment is shown in figure 2-14, and the low-voltage wiring is shown in figure 2-15. All wiring should be done according to NEC, NEMA, and local wiring codes and standards. Throughout the system, all requirements of Schedule 2G of Title 30[5] have been met and simplicity of operation has been maintained.

Accommodations

The accommodations and arrangement of equipment for the LCC were developed according to the same constraints and concepts as for the ASC, except for modified quantities of everything required.

The same MIL-F-43231 military-type food packets are supplied for both the LCC and ASC, enough for 1,740 calories per man per day. Regular tap water (with 1 teaspoon of chlorox per 5-1/4 gallons of water) is stored in eleven (11) 17-1/2-gallon plastic containers.

The same Stello Products portable toilet is used for both the LCC and ASC, for the same reasons. Two are supplied in the LCC.

Fourteen triple free-standing steel bunks are spaced in pairs about 2 feet apart along one wall. The bunks bolt together and are easily assembled or dismantled. Although the bunks can stand alone, lashing each pair together and jamming them into the wall curvature is recommended for stability.

Chlorate candles are stored under the bunks. The baralyme and Hopcalite canisters are stored between bunk ends and the curved chamber wall. The 14 spare Personal Breathing Apparatus units can be hung on the bunks. The 20 fireproof "Nomex" blankets and spare coveralls are stored on the mattresses. An open aisle is provided at about maximum chamber height, and the remaining wall space is used to store food and water supplies.

The air diffuser is located directly beneath the shaft for maximum effectiveness and is structured to direct incoming air up and toward the chamber ends. Space under the diffuser is designed as the central control point for power and communications. One chemical and one water-type

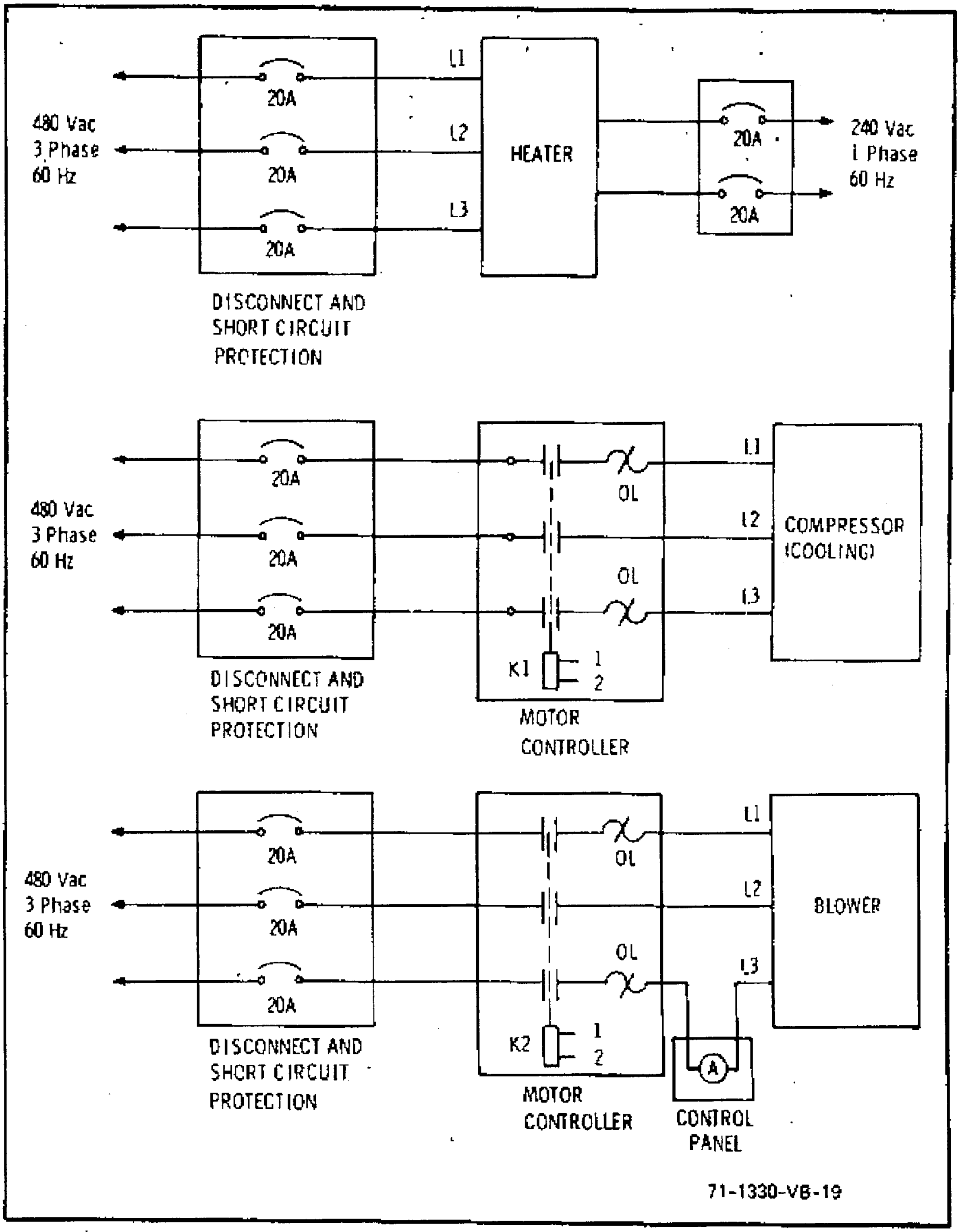

Figure 2-14. Surface High-Voltage Wiring

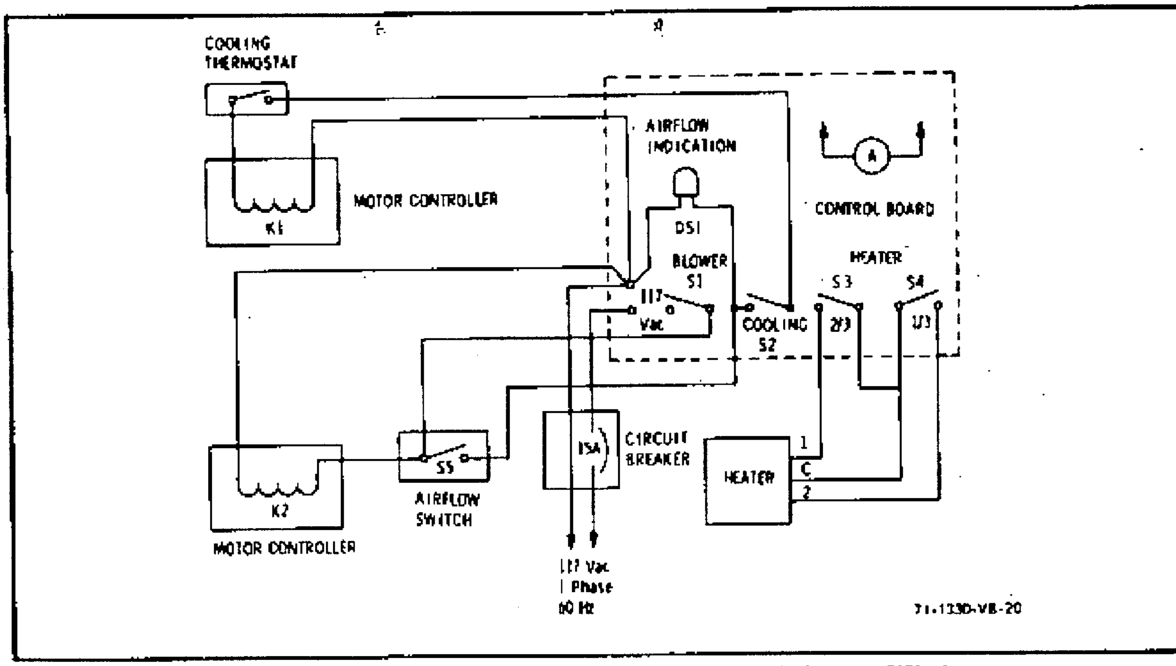

Figure 2-15. Surface Low-Voltage Wiring

fire extinguisher, the gas sampling equipment, and some furnishings are located against the wall opposite this area. The 5 atmosphere control units are spaced about equally along the chamber and on opposite walls to permit easy access and optimum gas diffusion.

One chemical toilet is located at each end. A water-type fire extinguisher and bundle of tools is also located at each end. Outside each end, a chemical extinguisher and several large tools (shovels, axes) are located.

The bulkhead with two doors contains the seismic and electromagnetic communications penetrations (see Volume III of this report). The EM equipment is stored in a large fiberglass box near the end until it is used.

The seismic transmitter and gas bottle are located near the EM equipment, with controls mounted to the wall. Because the transmitter-generated percussion may be detrimental to personnel, especially shock or concussion victims, this equipment may be kept and used outside the chamber.

Except for the diffuser, the chilled-water air-cooling system, and bulkhead penetrations, all equipment is mobile and can be moved to suit the immediate situation.

Cost Estimate

As part of the program effort, a preliminary cost analysis was conducted on the cost to construct the LCC. The results of this analysis are shown in table 2-11.

TABLE 2-II
ESTIMATED LCC CONSTRUCTION COSTS

Roof and side walls		
(Cost $107/ft - 84 ft needed)		$ 9,000
Floor and footings		
(Cost $25/ft - 84 ft needed)		2,100
Bulkhead with one door		
(Reinforced concrete)	$550	
(1 small door)	400	
(Door subframe assembly)	150	1,100
Bulkhead with two doors		
(Reinforced concrete)	$550	
(1 small door)	400	
(1 large door)	600	
(Door subframe assemblies)	300	1,850
Total estimated cost of structure for large chamber, less labor		$14,050

civil defense Technical Bulletin

Appendix 10

TB-5-3
May 1958
(Reprinted August 1958)

A DIGEST OF TECHNICAL INFORMATION

FAMILY SHELTERS FOR PROTECTION AGAINST RADIOACTIVE FALLOUT

PURPOSE

This bulletin provides guidance to engineers, architects, contractors, and the general public in planning family shelters for protection against the effects of radioactive fallout.

FALLOUT

General

Whenever a nuclear bomb is exploded near the ground, large amounts of earth and debris are drawn upwards by the ascending fireball. The resulting cloud may rise to a height of 80,000 feet or more. Radioactively contaminated particles which fall back to earth from this cloud are termed "fallout." Some of these radioactive particles are deposited close to the point of burst soon after the explosion, while others may be carried several hundred miles by the winds before they settle to earth.

Period of Shelter Occupancy

In any locality in the United States, fallout could require occupants to remain in shelter for two weeks or more. In many areas, radiation levels may permit leaving shelter, for intermittent periods or permanently, after 2 or 3 days. However, since the intensity of fallout at any specific place is impossible to predict prior to an attack, it is advisable to plan for a 2-week occupancy.

Radiation Hazard

There are several types of radiation associated with fallout. From the standpoint of shelter, however, the most significant hazard is from gamma radiation. Gamma rays, like X-rays, are highly penetrating, and to secure adequate protection from them special standards for shelter are required.

STANDARDS FOR FALLOUT SHELTERS

Shelter Dimensions

The shelter should provide for each occupant at least 12½ square feet of floor area and 80 cubic feet of volume. In general, ceiling heights should not be less than 6½ feet. The width of the entranceway should be kept to an absolute minimum, usually not more than 2 feet.

Shielding

(*a*) The shielding must have enough mass to reduce gamma radiation to a relatively harmless level. The less dense the material used, the greater the thickness required for a given degree of protection.

(*b*) As a general rule, a high degree of protection against gamma radiation will be afforded by an earth cover of 3 feet or an equivalent mass of other material or combination of materials. Approximate thicknesses required for other materials to afford protection equivalent to 3 feet of earth are: concrete, 24 inches; iron and steel, 7½ inches; and lead, 3 inches.

(*c*) The arrangement of the entranceway is important since harmful amounts of radiation may be scattered around corners. Therefore, the designs of the entranceways, shown on the attached drawings, should not be altered. It may be noted from the drawings that the radiation must make at least two right-angled turns before entering the main chamber. These changes of direction effectively reduce the intensity of radiation.

Ventilation

(*a*) In a basement shelter a tolerable and safe environment may be obtained by providing the means for natural ventilation, such as a grilled entrance door. Under-

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ground shelters, however, require the use of mechanical blowers or fans.

(b) The shelter ventilation system should be capable of supplying not less than 5 cubic feet of fresh air per minute per person in the main chamber, and means should be provided to exhaust the stale air. The actual intake of air which should be supplied to the shelter at any given time depends to a large extent on outside temperature conditions. For warmer temperatures, 5 cubic feet per minute per person is desirable. However, colder outside air may require a reduction in the amount delivered to the shelter, but this should never be less than 3 cubic feet of fresh air per minute per person. If practicable, the ventilating system should create a slight overpressure inside the shelter to prevent the infiltration of contaminated particles. The use of fuel-burning apparatus in the shelter area should be avoided.

(c) Suitable ventilating blowers or fans are commercially available at nominal cost (see Appendix A, page 4). Hand-operated centrifugal blowers of the type used in blacksmith forges have appropriate pressure-capacity characteristics. At a somewhat higher cost, small positive-displacement rotary blowers may be obtained with alternative hand-crank and electric motor drives, the latter feature being optional. While continuous operation of the ventilating blower at peak capacity would be best, intermittent operation on a short time cycle may be satisfactory. However, if the blower in a closed shelter is not operated for periods exceeding two hours, hazardous air conditions may result.

(d) Dry-type particulate air filters with cells or canisters containing a pleated filter material made of cellulose-asbestos or fine glass fibers are preferred for use in the ventilating systems (see Appendix A, page 4).

Radio Equipment

A battery-operated radio is necessary equipment for the shelter. If it is to be stored there, precautions should be taken to prevent its deterioration. A supply of spare batteries is highly desirable. Since batteries also deteriorate with time, replacements should be made at least once a year. The shielding required for radiation protection also drastically curtails effective radio reception. For this reason, radios used in shelters may require an antenna outside of the shelter itself. Since portable radios are made with widely differing circuit characteristics, it is impracticable to describe a single type antenna system suitable for all radios. However, two methods that have proven satisfactory with the radios tested are:

(a) Placing the radio near the underside of the entrance door.

(b) Running a lead-in wire from an outside antenna into the shelter, wrapping it several times around the radio in the direction that gives the best reception, and then grounding the end of the lead-in wire.

If neither of these methods proves successful, a local radio serviceman should be contacted for information on the most appropriate antenna system.

Food and Water Supply

At least a 2-week supply of food and water should be available. This may be required for survival even though the radiation level permits leaving the shelter in less than two weeks, since food may not be immediately available from normal sources. Foods that can be eaten without cooking are preferred. Packages of food should be in sizes which will meet the needs of one meal only. At least one-half gallon of water per person per day is needed for drinking and sanitation purposes. Gallon glass jugs, tightly capped, and carefully packaged to prevent breaking are recommended for long-term storage.

Sanitation

The sanitary disposal of human wastes is necessary for health protection. A small container, such as a hospital bedpan or other emergency toilet facility, should be provided. Contents should be disposed of in a covered watertight container. At least two 5-gallon holding containers are required for the initial shelter period. Following this period it may be possible to leave the shelter for short periods for disposal. These containers should be charged with a small amount of lime and water for odor control. A 10-gallon covered container for food refuse also should be included.

Miscellaneous Supplies

Other supplies that should be available include: a first aid kit; cots, bunks, or sleeping bags; blankets; flashlight and an extra supply of batteries, or a hand operated generator type of flashlight; can and bottle openers; eating utensils; toilet tissue, towels, and soap; and household tools.

Continuous low level lighting may be provided in the shelter by means of a 4-cell hot shot battery to which is wired a 150 milliampere flashlight-type bulb. Tests have shown that such a device, with a fresh battery, will furnish light continuously for at least 10 days. With a spare battery, a source of light for 2 weeks or more would be assured. A flashlight or electric lantern also should be available for those periods when a brighter light is needed.

FALLOUT SHELTER TYPES

Outside Underground Shelter

Many designs may be developed for an outside, underground, family fallout shelter which will provide reasonably adequate protection from radiation. Concrete, masonry, steel, pressure-treated wood, or other suitable construction material may be used. Three different shelter types are illustrated in the attached drawings (Appendixes B and C). It will be noted that all of these shelters are modifications of the basic underground family fallout shelter.

Basement Shelter

(*a*) In the construction of a new house with a basement, a family shelter may be incorporated in a corner of the basement in the manner illustrated in the attached drawing (Appendix D).

(*b*) The provision of fallout shelter equivalent to the basement shelter described above presents serious construction difficulties in existing houses. Placement of the large mass of shielding material for the roof of the structure in the restricted space, and the possibility of additional footings being required for the extra weight are the primary problems. A shelter of this type could be built into the basement of an existing house using lesser thicknesses of material, but a lesser degree of protection must be accepted by the occupants.

Aboveground Shelter

For areas of the country where underground shelters are not feasible, an aboveground shelter should be built. Any of the materials suggested for construction of an underground structure can also be used for this shelter. The total mass of shielding material, including the material of which the shelter is constructed, should be equivalent to three feet of earth. This may be provided by covering the structure with earth or sandbags. If the arrangement of the entranceway cannot meet the standards of paragraph c (p. 1) under "Shielding," the entrance door will require sandbagging from the inside.

The basic underground shelter, shown in Appendix B, with the entrance modified, could be placed aboveground and mounded over as described above.

Appendix A

A GUIDE TO CONTRACTS AND SPECIFICATIONS FOR USE IN FAMILY FALLOUT SHELTER CONSTRUCTION

If the services of a contractor are to be used in the building of a family shelter, it is generally advisable to have a written contract and technical specifications to supplement the drawings. A widely used and convenient contract form for construction of this size is the "AIA Short Form for Small Construction Contracts," which is available from the American Institute of Architects, the Octagon, Washington, D. C., for 25 cents. It would be impractical to write technical specifications to suit every local condition; however, the following summary of generally accepted construction materials and practices should be a useful guide:

EARTHWORK

The excavation should have side slopes gradual enough to prevent caving, or appropriate shoring should be provided. The soil from the excavation should be stockpiled near the site for later use as backfill if suitable for the purpose.

Material used for backfill and embankment should have debris, roots, and large stones removed before placement.

Backfill and embankment should be placed in horizontal lifts 12 inches thick or less and thoroughly tamped or rolled while in a damp condition.

The subgrade for the floor slab should be leveled and tamped to provide uniform bearing conditions for the structure.

The area surrounding the embankment should be sloped away at a minimum grade of 2 inches per 25 feet to provide good drainage.

CONCRETE WORK

The required compressive strength of the concrete in the attached OCDM designs is 3,000 pounds per square inch.

For details of concrete construction, the "Building Code Requirements for Reinforced Concrete (ACI 318–56)" should be followed. This publication may be obtained from the American Concrete Institute, P. O. Box 4754, Redford Station, Detroit 19, Mich., for one dollar.

DAMPPROOFING AND WATERPROOFING

Dampproofing and waterproofing specifications may be obtained from the nearest Federal Housing Administration Office, or any commercially acceptable specification may be used.

METAL WORK

The OCDM family fallout shelters were designed using deformed intermediate grade billet steel reinforcing bars. However, the shelters may be designed using other types of deformed steel bars. It is important that the builder insure that the bars to be used conform to the ACI Building Code referred to under "Concrete Work" above.

There are many types of commercially produced metal roof hatches that will adequately serve as shelter doors. However, as long as the door is weatherproof and durable, a job-made wooden door would be suitable.

The ventilation piping in the shelter should be installed in accordance with the practices outlined in the "National Plumbing Code (ASA A40.8–1955)." This publication may be obtained from the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y., for $3.50. All piping should be galvanized.

The rungs in the entrance hatch are standard ¾-inch deformed reinforcing bars. The unembedded portion should be painted to prevent rusting.

VENTILATING EQUIPMENT

Suitable ventilating blowers, air filters, and roof ventilators are available from many sources of supply, although fabrication details, and consequently the installation requirements, will differ for equipment furnished by the various manufacturers.

Positive-displacement blowers having both electric motor and geared hand-crank drives are manufactured by Roots-Connersville Blower Division, Connersville, Ind. Small centrifugal blowers having a geared hand-crank drive are made by the following manufacturers:

Buffalo Forge Co.,
450 Broadway,
Buffalo, N. Y.

Champion Blower and Forge Co.,
Harrisburg Ave. and Charlotte St.,
Lancaster, Pa.

Air filters of the type used for engine or compressor intake pipes are manufactured by the following concerns:

Dollinger Corp.
6 Centre Park,
Rochester 3, N. Y.

Fram Corp.,
Providence 16, R. I.

Purolator Products, Inc.,
970 New Brunswick Ave.,
Rahway, N. J.

Roof ventilators are made by the following manufacturers:

Air Devices, Inc.,
185 Madison Ave.,
New York City 16, N. Y.

G. C. Breidert Co.,
P. O. Box 1190,
San Fernando, Calif.

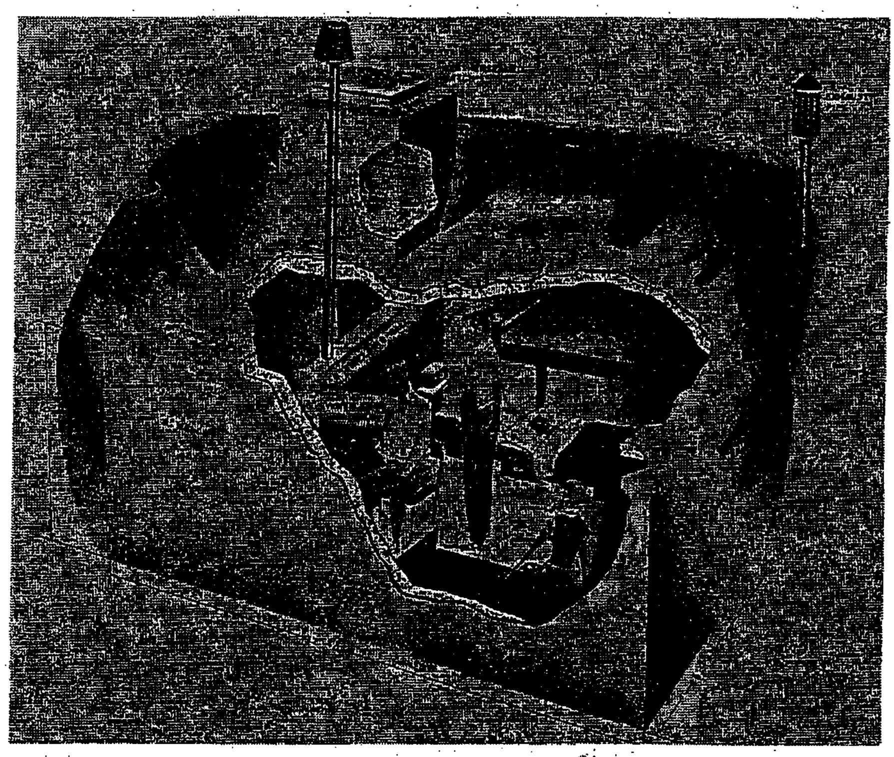
Penn Ventilator Co.,
3252 Goodman Ave.,
Philadelphia 40, Pa.

The names of specific manufacturers of blowers, filters, and roof ventilators are given only as examples, and do not denote a preference for their products. Local contractors, dealers, or distributors of heating, ventilating, and air conditioning equipment may be consulted when selecting equipment for a protective shelter.

Appendix B

THE BASIC UNDERGROUND FAMILY FALLOUT SHELTER

This reinforced concrete shelter has been designed to provide a high degree of protection from radioactive fallout for up to six adult occupants. The drawings show the shelter covered by an embankment 2 feet 3 inches high. If desired, the embankment may be eliminated by placing the roof of the shelter 2 feet 3 inches below ground level. The selection of which type of earth cover to use is optional since there is no significant difference in the amount of protection afforded. If the embankment is used, however, its slopes should be seeded or treated to prevent erosion.



Appendix B, Drawing No. 1.—FAMILY FALLOUT SHELTER (4 to 6 persons).

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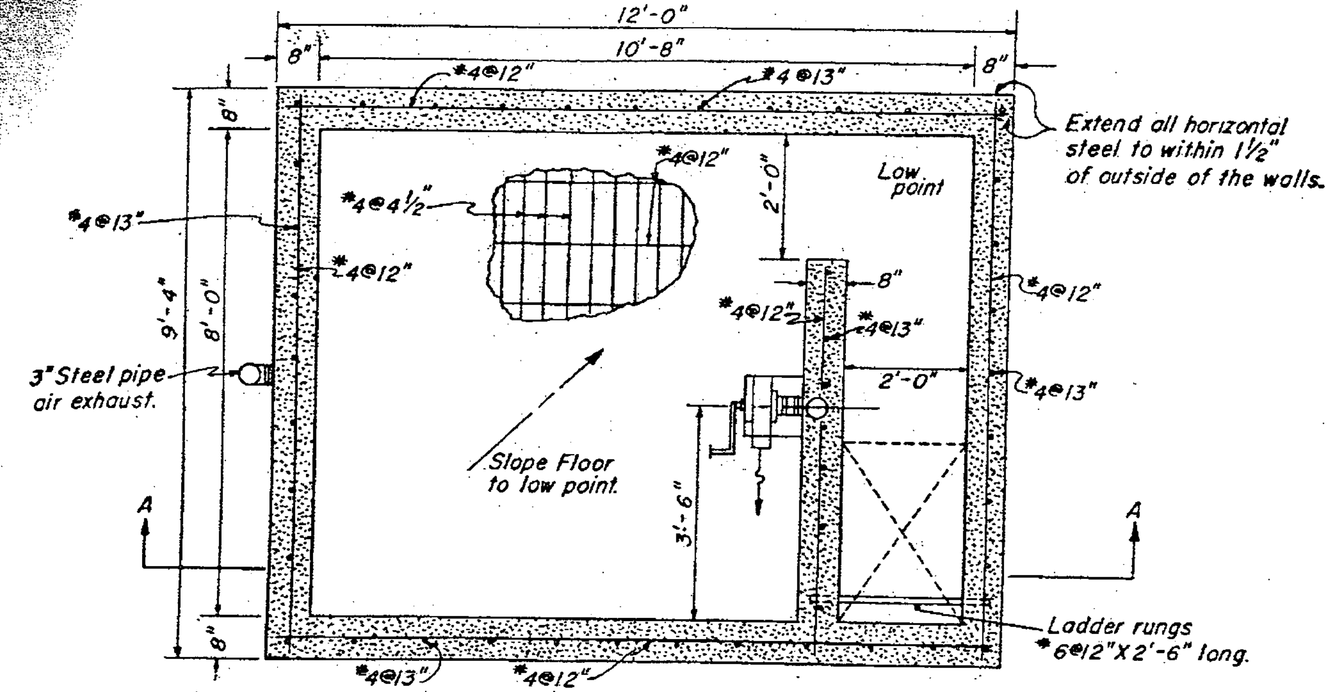
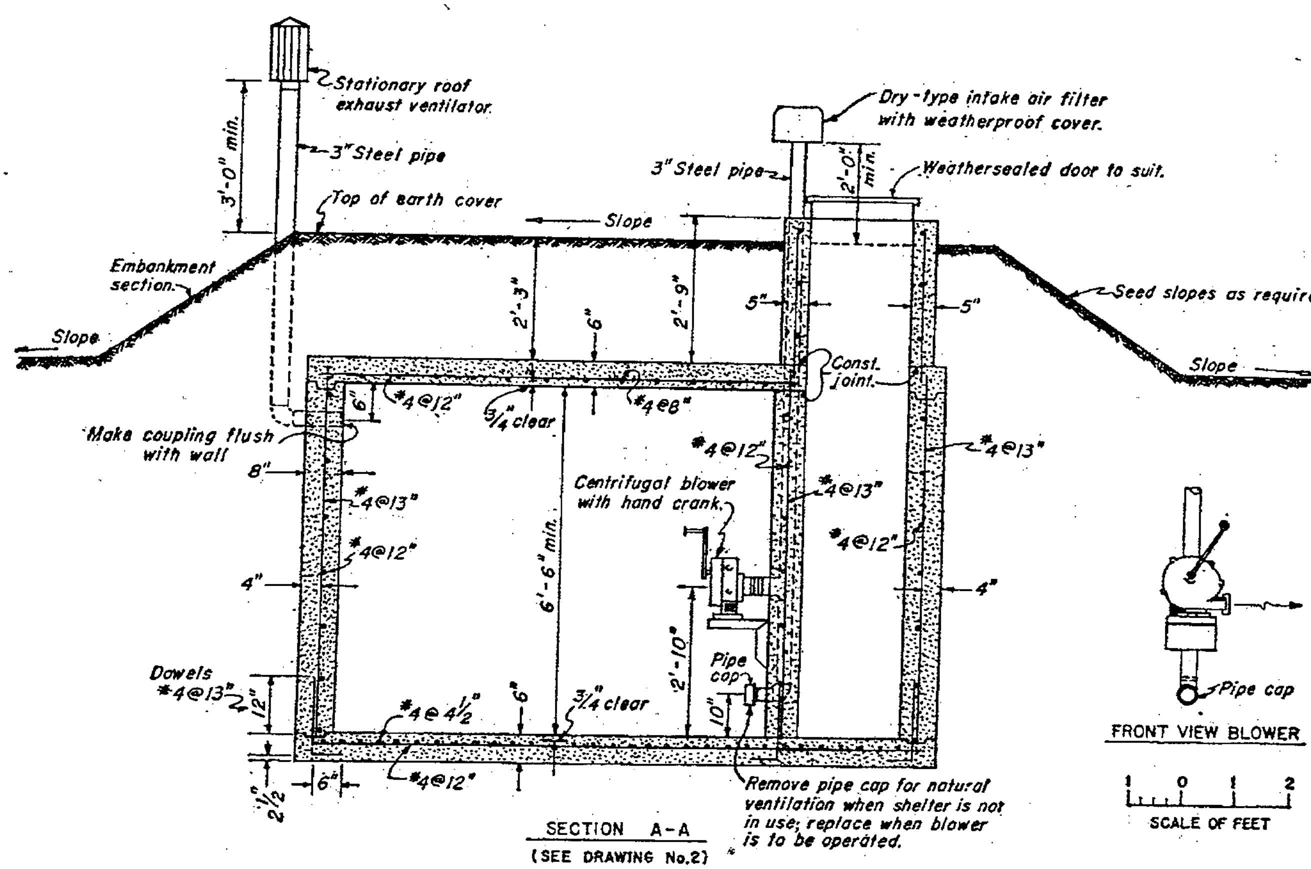
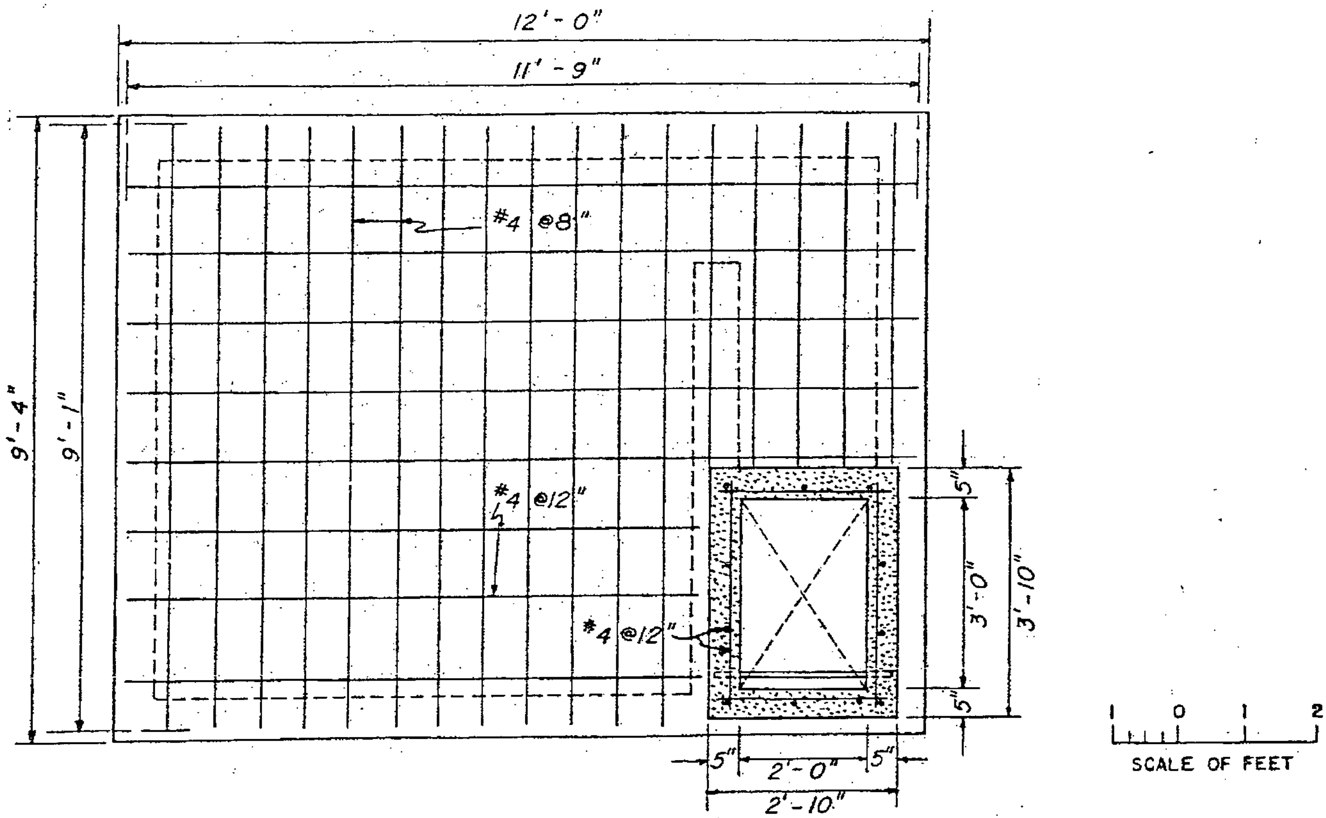


Appendix B, Drawing No. 2.—BASIC UNDERGROUND FAMILY FALLOUT SHELTER—Plan.



Appendix B, Drawing No. 3.—BASIC UNDERGROUND FAMILY FALLOUT SHELTER—Longitudinal Section.



Appendix B, Drawing No. 4.—BASIC UNDERGROUND FAMILY FALLOUT SHELTER—**Roof Slab and Entranceway.**

Appendix C

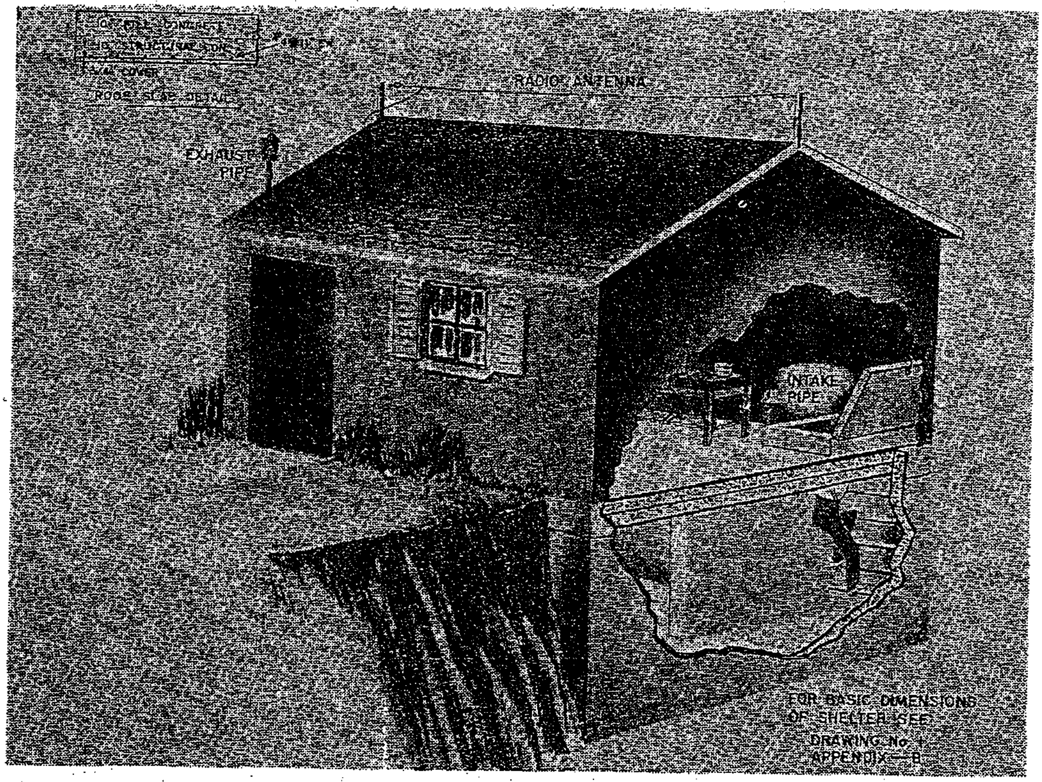
THE BASIC UNDERGROUND FAMILY FALLOUT SHELTER INCORPORATED INTO SMALL BUILDINGS

The basic underground family fallout shelter can be incorporated into the plans of basementless houses, garages, garden or tool houses, and the like (see drawings 1 and 2). There are only two structural modifications required. First, the slab thickness of the roof must be increased to 20 inches, and second, a "collar" of concrete or masonry must extend above the entranceway opening in the roof slab. The reinforcing bars of the walls and floor slab must be the same as in the basic shelter.

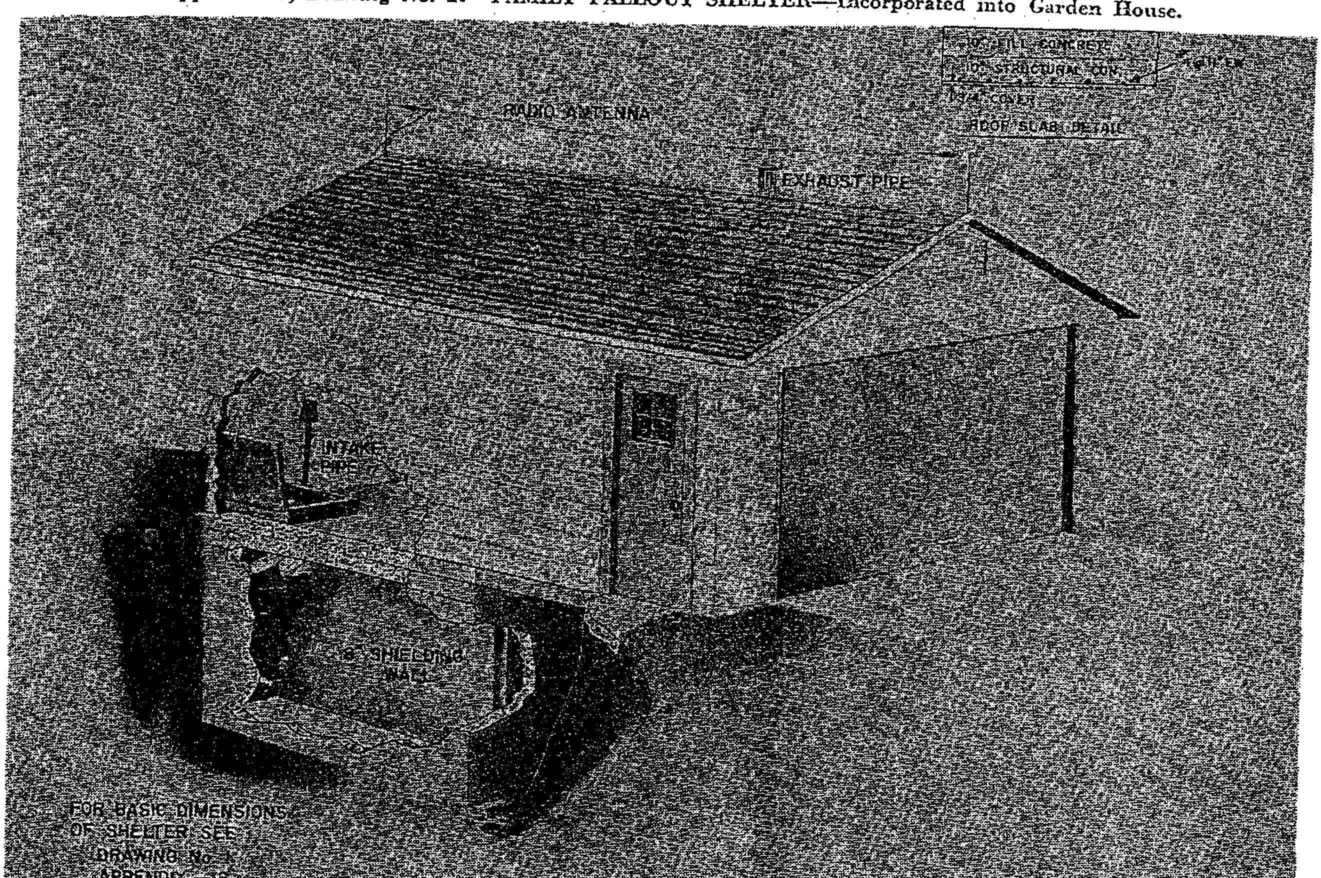
To meet recognized code requirements economically, the roof slabs should be placed in two 10-inch layers. The lower layer should contain the minimum amount of reinforcing steel required by code. The upper layer is for radiation protection only, and it should be placed and compacted with the same care as the structural concrete.

The "collar" should have a minimum height of 12 inches and width of 12 inches. These dimensions are based on radiation considerations. Since most commercially available door hatches have minimum inside dimensions of 2 feet 6 inches x 3 feet, the collar is of ample size to accommodate them, even though the actual opening is narrower.

The ventilation system should contain the same components as the basic shelter; however, the intake may be located within the small building and the exhaust outside, as shown on the drawings.



Appendix C, Drawing No. 1.—FAMILY FALLOUT SHELTER—Incorporated into Garden House.



Appendix C, Drawing No. 2.—FAMILY FALLOUT SHELTER—Incorporated into Garage.

THE BASEMENT CORNER ROOM FAMILY FALLOUT SHELTER INCORPORATED INTO NEW CONSTRUCTION

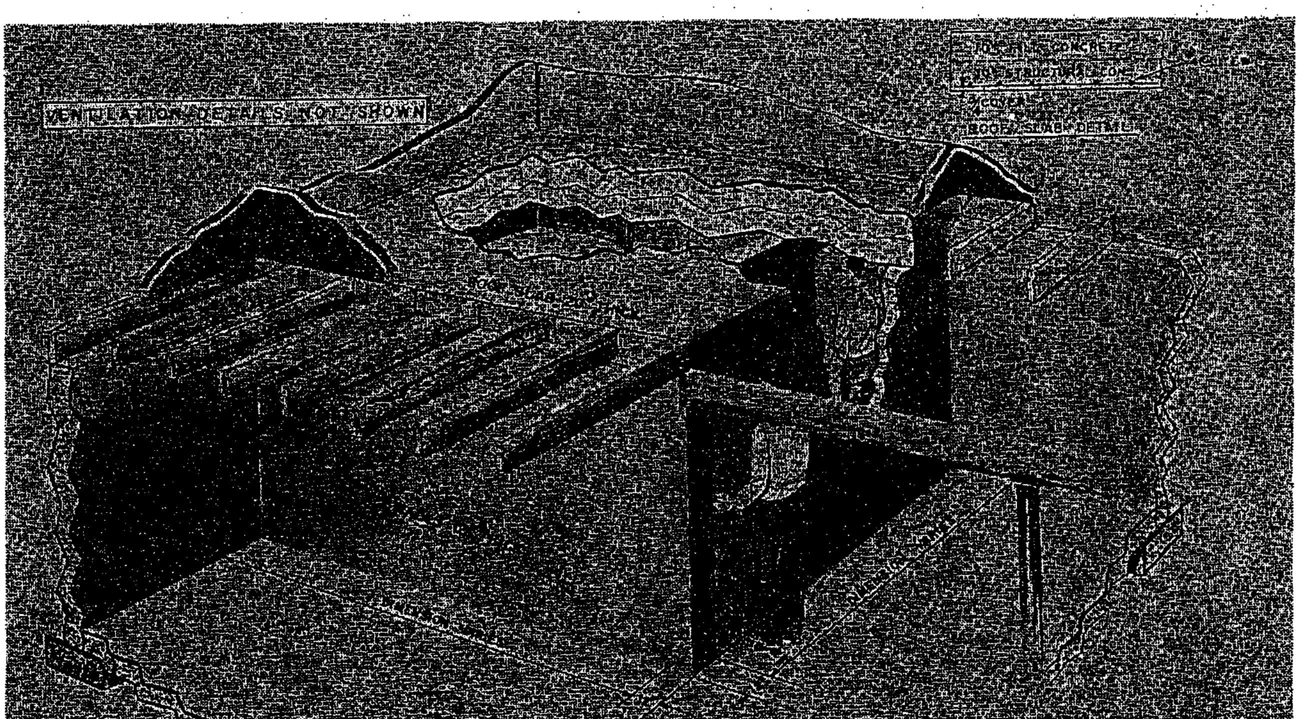
In this design (drawing No. 1) the two exterior walls of the shelter also serve as house foundation walls and the top of the roof slab is used as the floor for a room above.

Any contractor should be able to construct the basement corner room shelter without difficulty. Special care, however, should be taken in shoring the formwork for the heavy roof slab. Although not shown on the drawing, conventional wall footings should be added under the interior walls of the shelter.

To meet recognized code requirements economically, the roof slab should be placed in two 10-inch layers. The lower layer should contain the minimum amount of reinforcing steel required by code. The upper layer is for radiation protection only, and should be placed and compacted with the same care as the structural concrete.

The shelter may be built with either a natural or mechanical ventilation system. Natural ventilation may be achieved by having two grilles or louvers about 1 foot square in the entrance door. One grille should be near the top and the other near the bottom of the door.

If a mechanical system is used, it should contain the same components as the basic underground family fallout shelter except that a grille in the door may be substituted for the exhaust pipe.



Appendix D, Drawing No. 1.—BASEMENT FAMILY FALLOUT SHELTER (4 to 6 persons).

U. S. GOVERNMENT PRINTING OFFICE: 1958

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 5 cents

Explosions and Refuge Chambers

R. Karl Zipf, Jr., Ph.D., P.E.
Kenneth L. Cashdollar

Effects of blast pressure on structures and the human body

The following table 1, based on Department of Defense data from Glasstone and Dolan (1977) and Sartori (1983), summarizes the effects of increasing blast pressure on various structures and the human body. This data originates from weapons tests and blast studies to assess the effect of blast overpressure on structures and people. This data provides some guidance on the possible effects of mine explosions on miners.

Table 1 – Effect of various long duration blast overpressures and the associated maximum wind speed on various structures and the human body.

Peak overpressure	Maximum wind speed	Effect on structures	Effect on the human body
1 psi	38 mph	Window glass shatters	Light injuries from fragments occur
2 psi	70 mph	Moderate damage to houses (windows and doors blown out and severe damage to roofs)	People injured by flying glass and debris
3 psi	102 mph	Residential structures collapse	Serious injuries are common, fatalities may occur
5 psi	163 mph	Most buildings collapse	Injuries are universal, fatalities are widespread
10 psi	294 mph	Reinforced concrete buildings are severely damaged or demolished	Most people are killed
20 psi	502 mph	Heavily built concrete buildings are severely damaged or demolished	Fatalities approach 100%

The human body can survive relatively high blast overpressure without experiencing barotrauma. A 5 psi blast overpressure will rupture eardrums in about 1% of subjects, and a 45 psi overpressure will cause eardrum rupture in about 99% of all subjects. The threshold for lung damage occurs at about 15 psi blast overpressure. A 35-45 psi overpressure may cause 1% fatalities, and 55 to 65 psi overpressure may cause 99% fatalities. (Glasstone and Dolan, 1977; TM 5-1300, 1990)

Table 1 also shows the maximum wind speed associated with the given overpressure. In mine explosions, as in war-related explosions, it is the blast wind resulting from the blast overpressure that leads to injuries and fatalities. The human body may be thrown violently into objects and receive blunt force trauma; conversely, large objects may be thrown into persons resulting in crush injuries, or else projectiles launched by the blast wind may penetrate the body. The susceptibility of personnel to blast effects depends on their proximity to nearby objects and possible projectiles. Miners standing in the open and away from projectiles may survive higher blast overpressures than those standing near a solid wall or object. Personnel sitting within the confines of mining machines may receive some protection from both blunt force trauma and projectiles. While it is impossible to determine the exact correlation between blast wave overpressure and fatality rate for personnel in an active underground mine, the data in table 1 above appears to provide useful guidance.

Explosion scenarios for refuge chambers and outby refuge stations

Figure 1 illustrates several possible locations of rescue chambers and outby rescue stations in a typical mining operation with three working sections, 1) a longwall face, 2) a longwall development heading and 3) a mains development heading. Refuge chambers are located near each working face where the greatest concentration of mine workers is expected, and outby refuge stations are located periodically along the primary escape route.

Multiple methane explosions with or without coal dust might occur within a mine. A first explosion might occur 1) on the working face, either longwall or room-and-pillar, 2) within a sealed area or 3) at some location outby the working face such as a shaft bottom, bleeder system or along the mains. This first explosion could disrupt the ventilation system severely and lead to a second and possibly subsequent explosions. These subsequent explosions will most likely occur close to the first explosion, but they could occur at some distance away as well. According to the MSHA investigation reports, the Willow Creek mine disaster in 2000 involved 4 explosions, and the Jim Walters Resources mine disaster in 2001 involved 2 explosions. Most of the fatalities occurred in the second and later explosions.

The areal extent of an explosion depends on many factors, but most important are the amount of methane gas available to fuel the explosion and the extent of coal dust participation. We define a "small" explosion as one with flame travel of less than 100 feet, a "medium" explosion as one with flame travel of several hundred feet, and a "large" explosion as one with flame travel of more than 1000 feet. Small and medium explosions likely affect just one working section, whereas a large explosion could affect the entire mine. Usually, methane explosions at the face or outby range from small to medium explosions traveling hundreds of feet. If coal dust becomes involved, the explosion may become "large" and travel thousands of feet.

With any explosion, the crew's proximity to that explosion dictates their likelihood of survival and the likelihood they can make it to a refuge chamber, or preferably escape completely. In this analysis, we assume that a medium or large explosion, less than 1000 feet away, will likely kill or severely incapacitate the crew instantly and render the need for the refuge chamber moot. Such a scenario could occur at any working face, longwall or room-and-pillar. If a small to medium explosion occurs far from the crew, defined as more than 1000 feet away, we assume that many of the crew will likely survive to enter the refuge chamber. We are therefore designing for a "survivable" explosion.

With reference to figure 1, table 2 illustrates the relationship between the crew location, the location of a "medium" size explosion, and the likely effect on each work crew, which is either fatal immediately, survivable with rescue chamber and survivable with immediate escape.

Table 2 – Relationship between crew location, the location of an explosion and the possible effect on the work crew.

Crew Location	Location of "Medium" Explosion			
	Longwall (at or near face)	Longwall Development (at or near face)	Mains Development (at or near face)	Other location along primary escapeway
Longwall	Fatal	Chamber or Escape	Escape	Chamber or Escape
Longwall Development	Chamber or Escape	Fatal	Chamber	Chamber or Escape
Mains Development	Chamber or Escape	Chamber or Escape	Fatal	Chamber or Escape
Inby the Explosion	Not applicable	Not applicable	Not applicable	Chamber
Outby the Explosion	Escape	Escape	Escape	Escape

Pressure design criteria for refuge chambers and outby refuge stations

Refuge chambers and outby refuge stations may be designed to resist an overpressure of at least 5 psi. If a miner miraculously survives a 5 psi blast in the vicinity of a refuge chamber, that person is assured that the refuge chamber will also survive.

The state of West Virginia has ruled that refuge chambers will resist a blast overpressure of 15 psi. This pressure design criterion is apparently conservative and errs on the side of safety.

Anchorage requirements for refuge chambers and outby refuge stations

Refuge chambers and outby refuge stations could be anchored to the floor or otherwise rendered immovable in some way. A 6-ft-wide by 5-ft-high refuge chamber has a cross-sectional area of 4,320 square inches. A 5 psi blast overpressure subjects the chamber to a lateral force of 21,600 pounds. Therefore, the chamber requires anchorage or some other means to render it immobile in a mine entry.

To demonstrate the effects of explosion pressure on objects, an LLEM test moved a 1,560 pound object about 79 feet. The explosion pressure on the object was estimated at 3.5 psi and lasted less than 7 milliseconds. The exposed cross-sectional area is estimated at about 900 square inches, and therefore, the total force on the object was about 3,150 pounds for a few milliseconds. Again, this force moved the 1,560 pound object about 79 feet.

Explosion debris protection for refuge chambers and outby refuge stations

Figure 2 shows the debris pattern from a failed seal in a test at the Lake Lynn Experimental Mine. The explosion was initiated in the C drift and reached a maximum pressure of 90-100 psi inby the seal. Debris from the failed seal, from cribs built near the seal, and from a stopping outby the seal extended about 1100 feet from the original seal location.

The most important point to note from this debris pattern is the general lack of debris in the cross-cuts at right angles to the "line of fire" from the explosion. The debris travels in a straight line. In terms of debris protection, there is an advantage to placing refuge chambers in cross-cuts if the debris from blown-out seals is likely to travel out the entries. If the seals are perpendicular to the entries or if there are stoppings in the cross-cuts, then there would be significant debris in the cross-cuts.

Figure 3 shows several possibilities for locating refuge chambers in the vicinity of a typical development heading, such as in cross-cuts or in stub entries in various possible locations. A stub entry requires ventilation for use as a refuge chamber locale.

Design guidelines for refuge chambers located near the working face and outby refuge stations located along primary escapeways

1. The refuge chamber should survive an explosion overpressure of at least 5 psi. A refuge chamber designed for this pressure could provide sanctuary to a miner who survives such explosion pressure.
2. The outby refuge station should survive an explosion overpressure of at least 5 psi. A miner who survives such explosion pressure, should find the outby refuge station intact.
3. Locate refuge chambers less than 1000 feet from the working face or other concentrations of the underground mining workforce.
4. Locate refuge chambers and outby refuge stations in a cross-cut between two intakes, insofar possible. This practice can help protect the refuge chamber from explosion debris.
5. Alternatively, locate refuge chambers and outby refuge stations in a stub entry perpendicular to the main entries and in between crosscuts. See figure 3 to illustrate. Note that the stub entry would require proper ventilation. If the chamber is at the end of a stub entry, another advantage is that it would not be moved by the explosion pressure.

6. Locate refuge chambers and outby refuge stations out of the possible explosion path or "line-of-fire" from sealed areas, insofar possible.
7. Locate refuge chambers and outby refuge stations at least 1000 feet away from seals, insofar possible.
8. Locate refuge chambers and outby refuge stations away from or around a 90 degree corner from major debris sources such as cribs, stoppings, conveyor belt structure or large stores of supplies that could become flying objects, insofar possible.
9. Protect the refuge chamber and outby refuge station doors and other important structures from the possibility of damage from any likely source such as routine moving and any debris from an explosion.
10. Shield refuge chambers and outby refuge stations from possible flying debris with sacrificial structures or some other technique, insofar possible.
11. Anchor refuge chambers and outby refuge stations firmly to the floor or assure that it remains stationary by some means.

References

Glasstone S, Dolan PJ, eds. [1977]. The effects of nuclear weapons. 3rd ed. U.S. Department of Defense and the Energy Research and Development Administration.

Sartori, L. [1983]. The effects of nuclear weapons, Physics Today, March, pp. 32-41.

ARMY Manual TM 5-1300 [1990]. Department of the Army, Washington, DC, 1990

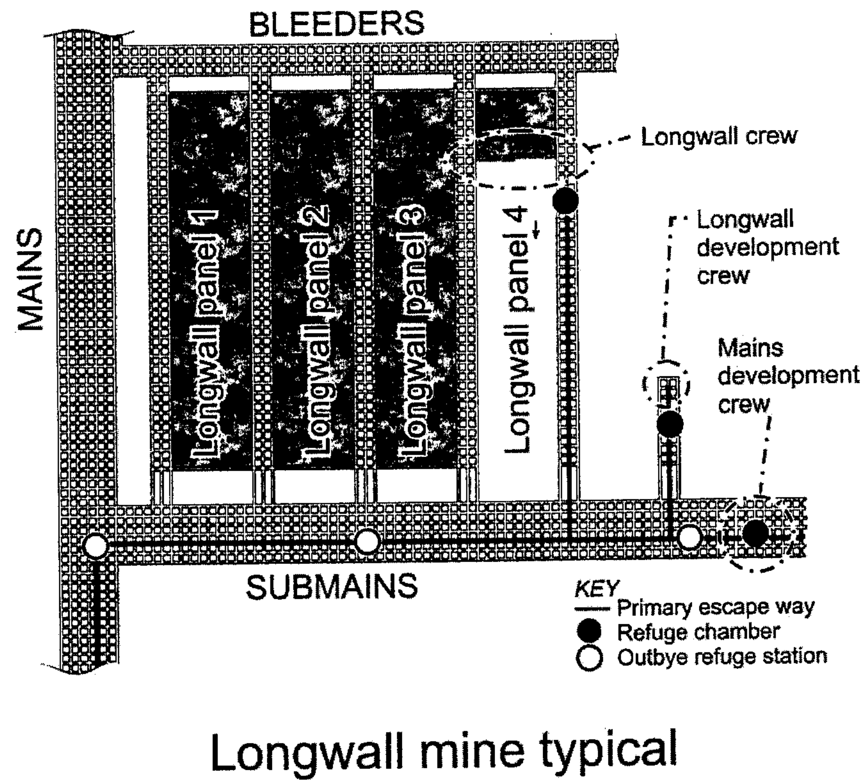


Figure 1 – Typical longwall mine layout showing the likely locations of refuge chambers and outby refuge stations.

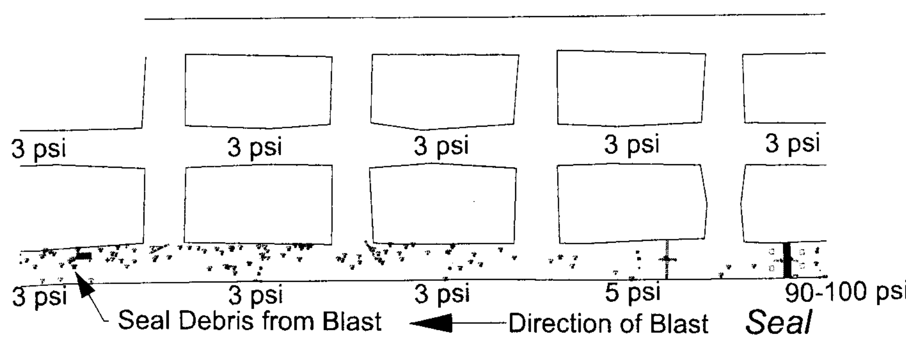


Figure 2 – Most debris from an explosion remains in entries parallel to the direction of the blast. Little debris affects entries perpendicular to the blast. Locate refuge chambers in cross-cuts at right angles to the most likely "line of fire" from an explosion to protect the refuge chambers from projectiles.

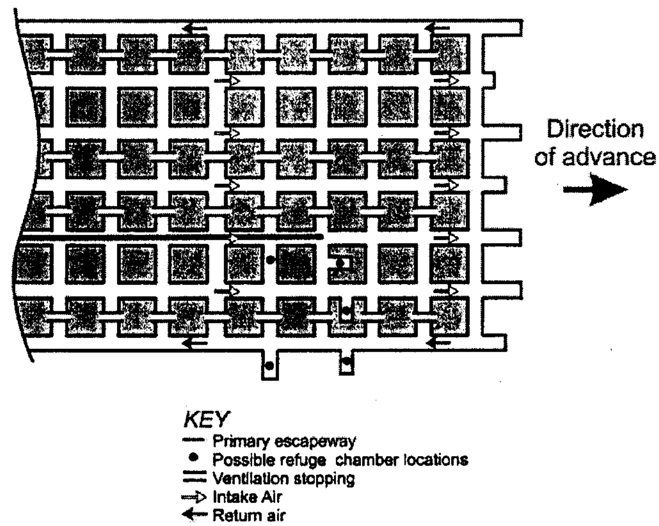


Figure 3 – Possible locations for refuge chambers in a development heading. The main options are a cross-cut or a stub entry. Note that a stub entry would require proper ventilation.

A mining research contract report
OCTOBER 1983

DEVELOPMENT OF GUIDELINES FOR RESCUE CHAMBERS, VOLUME I

Contract J0387210

Foster-Miller, Inc.
50 Second Avenue
Waltham, MA 02254

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

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			14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

The U.S. Bureau of Mines (USBM) awarded a contract to Foster-Miller, Inc. to develop guidelines for designing, constructing, stocking, and maintaining rescue chambers in underground mines. This report develops information and recommendations which could be used by a mine operator who desired to install a rescue chamber.

Volume I covers the following major areas: atmospheric life support, configuration and construction, chamber location, power and lighting, equipment and supplies, communications, and psychological aspects and training.

Volume II contains the following appendices: History of Barricading, Chamber Pressurization Considerations, Diffusional Infiltration of Gas, Compressed Air Storage, Location Examples, and Psychological Aspects.

17. Document Analysis a. Descriptors

Rescue Chambers
Refuge Chambers
Barricading
Mine Rescue

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 79
	20. Security Class (This Page) UNCLASSIFIED	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77)

FOREWORD

This report was prepared by Foster-Miller Associates, Inc., Waltham, MA, under USBM Contract No. J0387210. The contract was initiated under the Minerals Health and Safety Technology Program. It was administered under the technical direction of Pittsburgh Research Center with John Kovac acting as Technical Project Officer. Larry Guess was the Contract Specialist for the USBM. This report is a summary of the work recently completed as a part of this contract during the period July 1978 to July 1982. This report was submitted by the authors on 31 October 1983.

All cost information in this report is stated in 1983 dollars. Most of the cost data was assembled during 1979; these figures were increased by 40 percent to reflect up-to-date costs as of mid-1983.

The technical effort was performed by the Mining Division of the Engineering Systems Group, with John McCoy as Program Manager and Randy Berry as Senior Engineer. Donald Mitchell did the research and analysis of the History of Barricading.

VOLUME I
TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

1.1 Background

Under Section 315 of the 1969 Coal Mining Health and Safety Act, "the Secretary, or any authorized representative of the Secretary, may prescribe in any coal mine that rescue chambers properly sealed and ventilated be erected at suitable locations in the mine to which persons may go in case of emergency for protection against hazards." The rationale behind this law is that when miners must escape a mine, circumstances may arise that block exit routes. In this event, the trapped miners must be protected against noxious air and secondary explosions.

A 1970 report by the Committee on Mine Rescue and Survival Techniques of the National Academy of Engineering (1) stressed the importance of providing a shelter near the working face to protect miners against the hazards of explosions and noxious gases. This report speculates on the transfer of life-support technology from the aerospace industry to underground use. Emphasis was placed on the potential for technology application rather than feasibility or suitability.

Following the work of the National Academy of Engineers, the USBM contracted with Westinghouse Corporation to develop a self-contained rescue chamber. In the resulting program, completely self-contained chambers were designed, built and tested (2). The resulting chambers consisted of subassemblies which were maneuvered into a cross-cut where assembly was completed. All life-support provisions, atmosphere control, food and water, etc., were provided within the chamber. In testing, this chamber proved to be cumbersome and too labor intensive to erect. Furthermore, during explosion trials, seals between modules failed and man-testing of the chemically based atmosphere controls system performed marginally.

In light of this experience, the USBM contracted to Foster-Miller Associates (FMA) the task of designing reusable explosion-proof bulkheads. The concept behind this study was to construct a rescue chamber in a cross-cut by erecting a pair of explosion-proof bulkheads across the cross-cut. The results of this study (3) showed through explosion testing that the concept for constructing rescue chambers is feasible.

With the knowledge that an explosion-hardened chamber could be constructed, the USBM contracted FMA to develop a set of rescue chambers guidelines. The development of these guideline requirements and the specific guidelines are reported herein.

1.2 Philosophy of Escape

Controversy shrouds the implementation of underground rescue chambers. One side argues that rescue chambers are a life saving tool, while the other argues that rescue chambers may seduce miners away from escape thereby contributing to a net life risking situation. The background statement to the scope of work under which this program was performed indicated that, "In the event of a fire or explosion in a coal mine, the Bureau of Mines considers the primary means for men to escape from underground is by their own egress through properly designated and well maintained escapeways. However, in the event all exit routes are blocked, the trapped men must be protected against noxious air and secondary explosions until rescued." With this background, the FMA project staff has avoided entanglements in the controversy and has directed the program towards the pragmatic view that the job is to determine what is the best way to implement rescue chambers and not to determine whether rescue chambers are desirable, necessary or undesirable. Only through this sort of approach can the technology for rescue chambers be advanced, thereby allowing a rational decision on implementation.

1.3 General Purpose

These guidelines are to aid mine engineers and MSHA officials in the implementation of underground rescue chambers in coal mines. No argument is made here for the necessity of a rescue chamber in any particular mine. Mines are complex networks which must be considered on an individual basis to determine whether a rescue chamber is needed or appropriate for that mine. If there is a mine such that the probability of escaping is doubtful then the installation of a rescue chamber may be considered. These guidelines aid the engineers responsible in two ways:

a. Allow him to make a cost estimate of the various types of rescue chambers and to compare those costs to other mine modification(s) required to achieve an acceptable escape plan

b. Provide guidance for the detailed design and implementation of rescue chambers.

While this document prescribes many elements which must be considered and/or included, latitude is provided for the onsite engineer to design elements and implement methods consistent with local practice.

1.4 History and Practice

The concept of rescue (refuge) chambers dates at least from the 1930's, with documentation from the United States (1, 2, 3, 4, 6), Canada (7), the United Kingdom (8), Germany (9), and the USSR (10). 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. The obvious extension of barricading in an emergency is to have prepared barricaded sites (chambers, shelters, etc) provided with a kit of supplies useful for survival until rescue is achieved.

A detailed study of the history of barricading was undertaken as a part of this program. Forty-one mine accidents occurring during the time period 1940 through 1980 were identified in which barricading could be considered an appropriate safeguard. The results of this study are presented in Appendix A, History of Barricading. Figure 1 summarizes the actions of miners in those 41 accidents. It is clear that barricading has saved lives, and equally true that others have died behind barricades - usually because the barricade was poorly constructed, and/or because rescue was not timely enough. Properly-designed refuge chambers can improve upon barricades in terms of both better construction and lesser dependence on prompt rescue.

Installed underground rescue chambers have used forced air to control the breathing atmosphere. There are two methods used:

a. Air forced through a borehole from the surface

b. Air forced through compressed airlines from a surface compressor.

Examples of the borehole type have been built in a Pennsylvania coal mine* and at the Peckfield Colliery, United Kingdom (8).

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* Sites visited by program staff member.

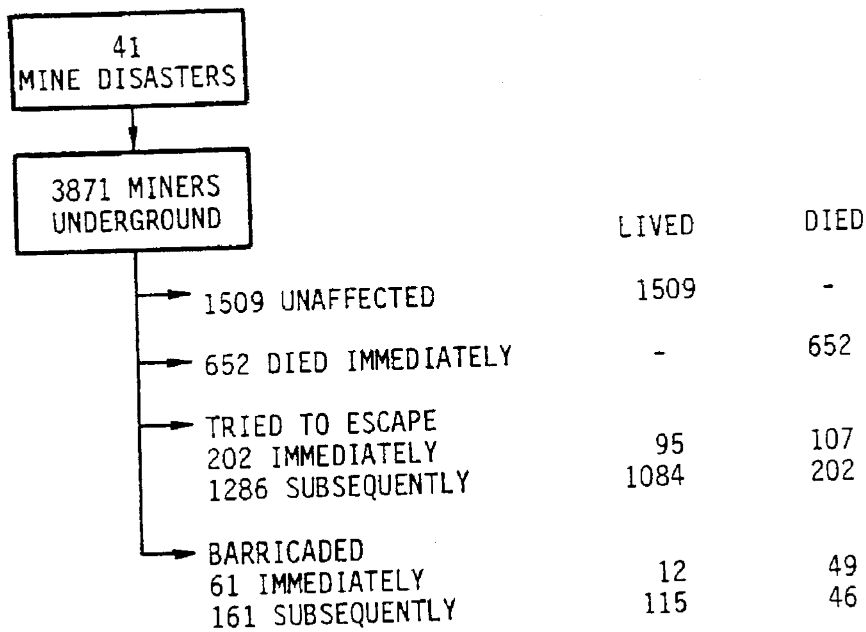

FIGURE 1. - Actions of miners in 41 fires and explosions, 1940 - 1980.

Compressed airline supplied chambers have been built in several metal/nonmetal mines in the United States* and Canada*, and a few coal mines in West Germany (9). At this writing, only one case is known of these chambers being used in an emergency. The 27 miners who waited for rescue inside this chamber in a Tennessee zinc mine were included in the lives saved by barricading data listed in Figure 1.

The USBM had two exprimental rescue chambers built under contract with Westinghouse in the late 1960's (2). These were explosion-proof chambers built on the surface and moved underground. Some of the atmosphere control system depended on a self-contained system for chemically processing and removing CO and CO_2 from the atmosphere. Tests of the life support equipment

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* Sites visited by program staff member.

indicated that while this approach was viable, more development and experience would seem necessary before the systems could be deemed reliable.

Since the most likely mine incident which would warrant the use of rescue chambers in coal mines is explosion and fire, and since secondary explosions can be expected, a key requirement is that the rescue chamber be hardened against explosion. The technology for building explosion-proof bulkheads exists. USBM had such bulkheads designed, built and successfully tested under contract with FMA (3). Hence, miners can be protected from explosion while inside the chamber.

The guidelines presented herein are based on historical practice and a conservative application of existing technology which is used in order to assure a high reliability. However, rescue chambers are like parachutes and lifeboats in that they must be considered an aid to possible survival, not a life assurance tool.

1.5 Organization of Guidelines

The guidelines are presented by topic subsection. Each subsection has a discussion of the topic, followed by specific, prescriptive guidelines for the topic.

Topics are presented in the following order:

a. Life support in chambers

b. Configureation and construction of chambers

c. Location procedures for chambers

d. Power and lighting for chambers

e. Equipment and supplies for chambers

f. Communication for chambers

g. Psychological and training aspects.

While the order is somewhat arbitrary, the rationale used was based on convincing the reader that life can be supported in a refuge chamber, then outlining the size, construction, location, equipment and training requirements.

2. ATMOSPHERIC LIFE SUPPORT IN RESCUE CHAMBERS

2.1 Technical Discussion

2.1.1 Philosophy

A safe, breathable atmosphere is of prime importance in maintaining human life. Toxic and/or oxygen-depleted atmospheres limit life expectancy to times of at most a few minutes, whereas people have survived days without water and weeks without food. If a satisfactory atmosphere is not assured for entrapped persons in a rescue chamber, all other efforts, plans and equipment associated with implementing, maintaining and using the chambers can be futile.

The methods for maintaining atmosphere control and shelters have been reported from a wide variety of sources (1-2, 4, 10-11). In addition to those sources, FMA used an inhouse expert on submarine life support equipment, a consultant at Scott Aviation, and various telephone calls were made to companies performing life support research such as Lockheed Missiles and Space Company and Mine Safety Appliance. Further, a National Technical Information Service (NTIS) search was studied. The results of the information found from all of these sources indicate that a large number of chemical methods for maintaining a life supporting atmosphere exist. However, none of the chemical processing methods appear to be suitable at this time for use in underground rescue chambers. Most of the high technology life support systems used on submarines or on space craft have experienced considerable specific development to those areas. Further, they depend upon large quantities of power to operate which may not be assumed when installed underground in emergency shelters. Also, it seems to be a characteristic of these high technology systems that they are prepared for specific missions; they are not kept in a standby mode to be used in case of emergency for underground rescue chambers.

The Westinghouse study cited earlier (2) had selected and tested a chemical life support system. Surface testing with this system indicated that there was a lack of technical development. This lack of development showed itself during man testing when some of the equipment experienced partial failures. The conclusion drawn from this exprience is that any high technology life support system intended for rescue chambers will have to undergo a program of research, development and demonstration before it is appropriate to be specified in guidelines. In the absence of this technical development, low technology systems with equipment familiar to mine mechanics must be specified.

To assure a satisfactory atmosphere, these guidelines have taken a very conservative technological approach for the supply of a breathing atmosphere to rescue chambers. Forced air is required to be supplied in all cases. Three types of chambers are permitted by these guidelines, as follows:

a. Air supplied through a borehole

b. Air supplied through redundant compressed airlines

c. Air supplied from a chamber located compressed air storage battery (cylinders).

While all three of these types of chambers can be designed to support life they are not of equivalent quality. Since a borehole is independent of all mine systems, therefore removed from any damaging effects of a disaster, the borehole can be assumed to be the most dependable for air supply in addition to providing a conduit for communication and transportation of material. The reliability of the airline supply depends on the high probability that one of two or more redundant airlines will survive the mine disaster events. Similar to the borehole, air supply from the airline is indefinite. This implies that life may be maintained in the chamber for many days after water, food and other supplies have been exhausted. This provides some extra time for rescuers to effect removal of entrapped miners. The reliability of stored compressed air depends on a rigorous testing and maintenance program during normal mine operations. An obvious weakness of the stored air chamber is that the supply is finite and that rescue efforts can not suffer any delays beyond the design time of the air supply. Cost is a less readily observable disadvantage of compressed air storage. For a single chamber installation with a design time of 2 weeks (210 mandays), compressed air storage requires an expenditure about ten times that of a borehole or an airline supplied chamber. Because of cost, it is expected that chambers with stored compressed air will be rare, and used only where the probability exists that persons can be recovered from the chamber within a few hours.

In the following subsections, the details of breathing air requirements and supply approaches will be described.

2.1.2 Human Respiration

The power source for vital human functions is the oxidation of carbon and hydrogen. The details of metabolism are beyond the scope of this discussion other than to state that food supplies the necessary carbon and hydrogen and that inhaled air supplies the necessary oxygen. The body can store food (converted to fat) for long periods of time; but oxygen cannot be stored for more than a few minutes, nor can life exist for more than a few minutes if the vital organs, for example the brain, do not receive fresh oxygen. Oxygen deprivation may occur through an inability to inhale, a lack of sufficient oxygen in the inhaled air, and by a chemical interference. An example of chemical interference occurs when carbon monoxide exists in the inhaled air. Carbon monoxide reacts in preference to oxygen with the hemoglobin in the red blood cells. Since hemoglobin is the vehicle by which oxygen is transported to body tissue, the cells are thus starved for lack of oxygen. When the tissue cells are deprived of oxygen below a certain level, unconsciousness and death results.

Other chemicals in the atmosphere may also produce adverse physiological effects. High levels of carbon dioxide trigger rapid respiration and can cause incapacitation through hyperventilation effects.

The general requirements for a breathable atmosphere are presented in Tables 1 through 4. The most likely mine disasters involve fire. Mine fires are characterized by poor combustion of carbon and hence high levels of carbon monoxide. Although carbon monoxide is the most important toxic gas, other toxic gases may be present also. Table 5 shows some other toxic gases with their tolerable limits.

The following subsection derives the quantitative requirements for breathing air.

2.1.3 General Breathing Air Requirements for Rescue Chambers

Developed in this subsection is the minimum airflow required by a person enclosed in a rescue chamber. Oxygen consumption and CO_2 exhalation rates for an assumed level of activity are examined. The results indicate that the minimum airflow requirement is set by the flow required to hold down the CO_2 level to a tolerable concentration.

TABLE 1. - Oxygen and air inhalation rates in human breathing*

Activity	At Rest	Moderate	Very Vigorous
Respiratory rate/minute	12-18	30	40
Air inhaled/respiration in.^{3}	23-43	90-120	150
Air inhaled, ft^3/day	335	2,625	5,000
(ft^3/min)	(0.23)	(1.82)	(3.47)
Oxygen consumed:			
ft^3/day	14.4	100.8	144
ft^3/min	0.01	0.07	0.10
Respiration quotient	0.75	0.9	1.0

*Mine Ventilation and Air Conditioning, Howard L. Hartman, The Ronald Press, New York, 1961.

TABLE 2. - Effects of oxygen deficient atmosphere*

Oxygen Content Percent by Volume	Effect on Humans
17	Faster, deeper breathing
15	Dizziness, buzzing in ears, rapid heart beat
13	May lose consciousness if exposure prolonged
9	Fainting, unconsciousness
7	Life endangered (equivalent to 5-1/2 mi. elevation)
6	Convulsive movements, death

*USBM Miners Circular No. 33 (1954), p. 2.

TABLE 3. - Effects of CO_2 levels on humans*

Carbon Dioxide Content Percent by Volume	Effects on Humans
0.5	Maximum allowable concentration** - no effect in 8 hr
1.0	Slight increase in lung-ventilation rate
2.0	Lung-ventilation rate up 50 percent
3.0	Lung-ventilation rate up 100 percent, headaches appear
5.0	Lung-ventilation rate up 300 percent - severe headaches and breathing is laborious
10.0	Can be endured for only a few minutes
12.0	Quick loss of consciousness

*Fire and Noxious Gases - Effect on Internal Environments of Protective Shelters - J. Enoch Johnson and Eugene A. Ramskill, U.S. Naval Research Laboratory.

**MAC is the Maximum Allowable Concentration as recommended by the American Conference of Governmental Industrial Hygienists, U.S. Public Health Service, and USBM.

TABLE 4. - Effects of CO levels on humans*

Carbon Monoxide Content Percent by Volume	Effects on Humans
0.01	Maximum allowable concentration - no effect in 8 hr
0.02	Headaches in 2 to 3 hr
0.04	Headaches and nausea in 1 to 2 hr
0.08	Headaches and nausea in 45 min, collapse in 2 hr
0.16	Headaches and nausea in 20 min and possible death in 2 hr
0.32	Headaches and dizziness in 5 to 10 min, and possible death in 30 min
0.64	Headaches and dizziness in 1 to 2 min, and possible death in 10 to 15 min

*Ibid.

TABLE 5. - Major gases evolved from materials used in mines (8)*

Material	Major Toxic Products
Neoprene conveyor belts	HCL, CO, CO_2, SO_2, CS_2, H_2S, benzene, formic acid
Polyvinyl chloride (PVC) conveyor belts	HCL, CO, CO_2, vinyl chloride, benzyl, chloride, benzene, toluene, phenol
Polystyrene-butadiene conveyor belts	HCL, CO, CO_2, H_2S, CS_2, methyl chloride
Urethane foams	HCL, CO, CO_2, aniline, chlorethanol
Wood (treated and untreated)	Acrolein, formaldehyde, acetaldehyde, HCN, formic acid

*Adaped from Paciorek, K.L., and others. Coal Mine Combustion Products Identification and Analysis, Annual Report, USBM Contract H0133004, August 1974.

Product	EEL (60 min)* (ppm)
Hydrogen chloride (HCL)	10
Carbon disulfide (CS_2)	50
Hydrogen sulfide (H_2S)	10
Acrolein (CH_2CHCHO)	0.2
Carbon monoxide (CO)	400
Sulfur dioxide (SO_2)	10
Formaldehyde (CH_2O)	3
Nitrogen dioxide (NO_2)	10

*Elevated exposure levels.

Note: Exposure above the listed EEL's would seriously impair emergency escape activities. (The EEL's are not strictly based on miner's work activity or environment and thus should be used only as a guideline to estimate danger from these gases).

The air supply must both provide oxygen and carry off the metabolic waste product CO_2 (assume no chemical removal of CO_2). The amount of O_2 a person requires and the amount of resulting CO_2 produced depends on the activity level (see Table 1). In these calculations, it is assumed that the activity level is four-fifths resting and one-fifth moderate activity. Steady-state calculations based on this mix of activity are justified by the assumption that there are several persons in the chamber with about one out of five persons on watch monitoring equipment and doing housekeeping tasks while the remaining four are resting or talking.

From Table 1 and the assumed activity level, the metabolic oxygen demand may be calculated as follows:

$$\frac{14.4 \text{ scf } O_2}{\text{resting man/day}} \times \frac{4}{5} + \frac{101 \text{ scf } O_2}{\text{moderate man/day}} \times \frac{1}{5} = \frac{31.7 \text{ scf } O_2}{\text{man/day}}$$

Similarly, the respired CO_2 may be calculated as follows:

$$\frac{10.8 \text{ scf } CO_2}{\text{resting man/day}} \times \frac{4}{5} + \frac{90.7 \text{ scf } CO_2}{\text{moderate man/day}} + \frac{1}{5} = \frac{26.8 \text{ scf } CO_2}{\text{man/day}}$$

If air is assumed to contain 21 percent oxygen (volume), the rate of air required to supply the necessary metabolic O_2 is calculated as follows:

$$\frac{31.7 \text{ scf } O_2}{\text{man/day}} \times \frac{1 \text{ scf air}}{0.21 \text{ scf } O_2} = \frac{151 \text{ scf air}}{\text{man/day}}$$

Table 3 shows the effects of CO_2 concentrations on people. If a CO_2 concentration of 1 percent is set as an upper design limit and if dilution is used to remove CO_2 from the atmosphere, then the air demand for dilution is:

$$\frac{26.8 \text{ scf } CO_2}{\text{man/day}} \times \frac{100 \text{ scf air}}{1 \text{ scf } CO_2} = \frac{2{,}680 \text{ scf air}}{\text{man/day}}$$

Since the airflow to dilute CO_2 (2,680 scf/man/day) is larger than the airflow to supply metabolic O_2 (151 scf/man/day), the dilution demand dominates, thus specifying the minimum air supply flow as:

$$\frac{2{,}680 \text{ scf}}{\text{man/day}} \times \frac{1 \text{ day}}{24 \text{ hr}} = \frac{112 \text{ scfh}}{\text{man}} \text{ or } \sim \frac{1.9 \text{ scfm}}{\text{man}}$$

If the chamber activity level should increase above the assumed value used to generate the minimum air supply requirement, then the CO_2 level will rise above the 1 percent value specified. However, there will still be sufficient oxygen supplied by the air for life support. This provides some safety factor since there are chemical adsorption methods which can be used to remove carbon dioxide in this type of emergency.

There are many methods reported for the removal of CO_2 by adsorption, however, the more practical candidates are adsorption on the following (11):

a. Soda lime

b. Baralyme

c. Lithium bromide.

Of these three, soda lime is recommended because it is the least costly. The adsorption process may be performed by placing the soda lime in packed bed canisters and using a blower to force air through the bed. A downstream air filter is needed to capture the entrained soda lime dust which is irritating to eyes and mucous membranes. Alternatively a passive bed CO_2 scrubber can be made by spreading the powdered soda lime out in a thin pad, for example on brattice, such that the area exposed to the atmosphere is large. Both methods have been used for control of submarine atmospheres. For rescue chambers, the passive pads are favored since it removes the need for a mechanical blower which might fail due to a long standby period.

Passive pads are not without drawback. Due to the irritating nature of soda lime powder and the fact that some dust will become suspended during the process of spreading out the powder, some discomfort is expected. However, this is an emergency procedure expected to be used only if the activity level increases the CO_2 level to the uncomfortable range; it is not intended to be used continuously.

The procedure for making a passive CO_2 scrubber is to spread the soda lime out on a brattice cloth, sheet, or blanket in as thin a layer as possible so as to expose a large surface area to the atmosphere. Gloves and goggles should be provided to protect persons handling the soda lime. Once the CO_2 level has been reduced to a tolerable level, the soda lime should be carefully removed from the pad and returned to the original storage cans.

The best method for determining the adsorption effectiveness is to measure the CO_2 concentration in the atmosphere. For quantitative estimates of the amount of soda lime required, consider that 4.2 lb of soda lime is needed to absorb 1 lb of CO_2. By previous calculation, it was shown that under assumed activity levels about 27 scf of CO_2 was produced per man/day. (The airflow requirement was based on removing this CO_2 rate.) If a safety factor of two is selected, then provisions should be made to adsorb an equivalent quantity of CO_2, that is, 27 scf. The quantity of soda lime required is calculated as follows:

$$\frac{27\left(\frac{\text{scf } CO_2}{\text{man/day}}\right)}{359\left(\frac{\text{scf}}{\text{lb-mole}}\right)} \times \frac{44\text{ lb* } CO_2}{\text{lb-mole } CO_2} \times \frac{4.2\text{ lb soda lime}}{1\text{ lb } CO_2} \cong 14\left(\frac{\text{lb soda lime}}{\text{man/day}}\right)$$

The Westinghouse study (2) indicated evolved heat will not be a problem.

The quantity of soda lime required for the safety factor of two may be determined by multiplying 14 lb/man/day by the design number of man/days. Approximate cost may be determined at the rate of \$0.50/lb for soda lime (1979 price).

2.1.4 Control of Hazardous Gas Infiltration

The source of hazardous gases in a disaster will be outside the chamber. Carbon monoxide is the most important toxic gas likely to be present during a fire/explosion disaster; methane is also likely to be present. Methane is an explosion hazard and in high enough concentrations can displace oxygen and contribute

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*Based on the U.S. Pharmacopoeia minimum of $\frac{0.238\text{g } CO_2}{\text{g soda lime}}$.

to suffocation. Experience (4) has shown that construction of a leak-free chamber for underground use is improbable. Therefore, if the pressure outside the chamber becomes larger (for example, rising barometric pressure) than inside, hazardous gases can be forced into the chamber. While chemical methods exist (1, 2, 4) for controlling these substances (for example, the catalyst hopcalite for oxidation of CO to CO_2 and electro-chemical cells for oxidation of methane), no technology has been successfully developed and *demonstrated* for underground rescue chamber applications, where there are long standby times and very limited power available to operate the necessary machinery. The Westinghouse chamber program is the only attempt and demonstration was not successful (2). The approach recommended in these guidelines is to use the forced breathing air to pressurize the chamber thereby preventing the infiltration of hazardous gases.

In a steady-state, it is obvious that forcing air into the chamber will overpressurize it relative to the outside of the chamber. However, there are conditions such as barometric pressure changes, ventilation fans starting and stopping, temperature changes and moisture condensation which may allow the pressure outside the chamber to temporarily exceed the pressure inside the chamber.

The two most important pressure change conditions are due to barometric pressure changes and ventilation fan changes. Consideration of the effects of these changes is shown in Appendix B. Results of these considerations are that a forced air rate of 1.9 ft^3/min/man can keep pace with even the fastest changes in barometric pressure. However, exhaust fan stoppage (or forced fan starts) can require a larger forced air requirement than just for respiration. If the differential pressure across the fan is less than 10 in. of water, then forced air to the chamber should be the larger of 28 ft^3/min or 1.9 ft^3/min/man times the number of men. If the fan differential pressure is larger than 10 in. of water, than an analysis similar to that performed in Appendix B should be made, and the forced air flow adjusted upward to assure quality of chamber atmosphere.

An analytical check indicated that no infiltration into a pressurized chamber of hazardous gas should occur due to molecular diffusion against the over pressure of the chamber (Appendix C).

In summary, a forced air supply to a rescue chamber of 28 scfm or 1.9 scfm/man times the number of men (whichever is greater) should provide a suitable chamber atmosphere by providing:

a. Adequate oxygen

b. Removal of respired CO_2

c. Protection from infiltration into the chamber of hazardous gases.

2.1.5 Application

2.1.5.1 Borehole Supplied Air

As mentioned earlier, a rescue chamber with a borehole connected to the surface is of the highest quality because a borehole is totally isolated from the rest of the mine. The borehole can supply air, food, water, power and communications, thereby permitting a high degree of flexibility for coping with almost any emergency situation. Furthermore, if the entrapped miners are to be removed through a large escape borehole, the supply borehole aids as an accurate guide for the appropriate drilling location.

A schematic borehole configuration is shown in Figure 2. At the surface is an airtight shelter which protects the top of the borehole during standby periods, plus permitting the fan to force air down through the borehole while leaving the hole open for lowering materials when the chamber is in use. The borehole should have a minimum inside diameter of 6 in. so as to provide sufficient room for power and communication cables to be installed and still permit materials to be lowered or raised through the hole. The hole must be cased and grouted to preserve the hole and seal out water.

A means should be provided to allow air to escape *out of* (but not into) the rescue chamber and to measure the rate of outflow. The easiest method would be to install a vent tube which leads out of the chamber through a flow meter and a check valve to the mine. The flow through the vent tube must be maintained at or above the airflow requirement for that chamber. Since there will be air leaks around the bulkhead, the total airflow to the chamber will be larger than the value measured by the flowmeter. This is a conservative procedure which provides a safety factor. In addition to measuring airflow, the differential pressure between the chamber and the mine should be monitored with an aneroid pressure gauge (for example, a Magnehelic®). A liquid manometer should not be used as the liquid can be blown out of the tube thereby destroying the seal between the chamber and the mine.

For practical depths, the airflow resistance of a 6-in. borehole may be neglected since the flow resistance around the bulkhead is much greater than the borehole. Therefore, the borehole resistance need not be considered in fan selection. The

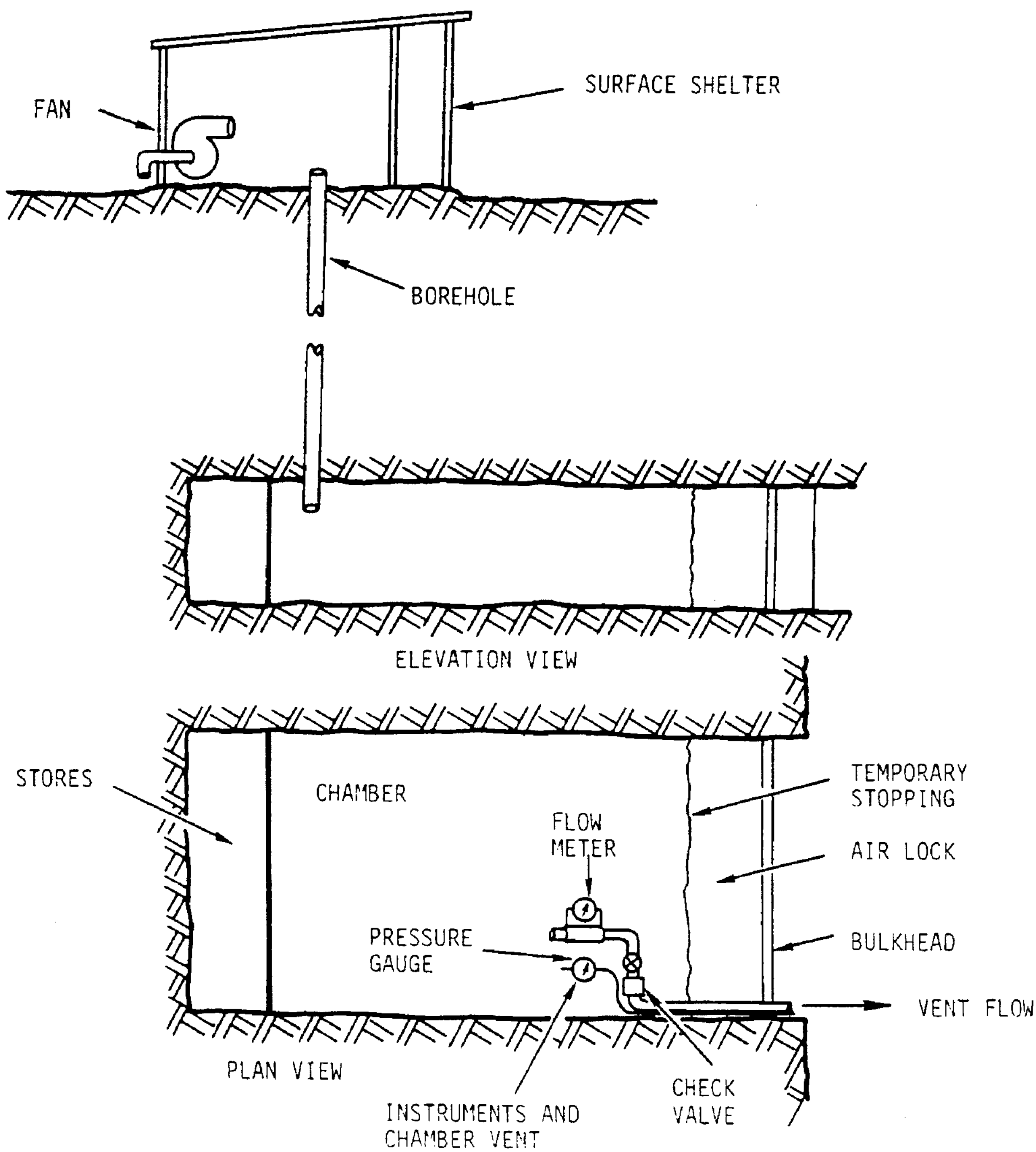


FIGURE 2. - Schematic of borehole supplied rescue chamber

best procedure for fan selection is to choose a fan that will supply an air flow of 3 to 4 times the required flow at a differential pressure across the fan of at least 5 in. of water plus the pressure of the mine if the mine ventilation is forced fan type. The extra flow capacity is to accommodate air leaks in surface shelter, borehole and chamber bulkhead.

On completion of construction, the system must be tested to ensure that proper airflow to the chamber is achieved. The surface shelter and the rescue chamber are to be closed up and the fan started. With the chamber pressurized to 5 in. of water or greater above the mine pressure, the design flow rate should be measured flowing through the vent tube. If design flow is not achieved, areas of air leaks should be sought out and sealed until sufficient flow is measured.

The major cost of a borehole connected rescue chamber is associated with drilling the hole. While cost can vary considerably with location, a typical cost based on recent FMA experience may be taken as $53*/ft cased and grouted. A rough typical cost of the surface shelter has been estimated at about $10,000* including fan, while the cost of instruments and controls (flowmeter, pressure gauge and valves, etc.) is estimated at about $700.*

2.1.5.2 Airline Supplied Air

A rescue chamber with airline supplied air has the advantage of an indefinite supply of air. It does not provide the flexibility of a borehole connected chamber since only air can be supplied through the airlines. Even with redundant airlines, safety is somewhat less than using a borehole because the airlines are passing through the mine and could be damaged or contaminated during the mine disaster.

A schematic of a rescue chamber with a compressed airline supply is shown in Figure 3. Two redundant compressed airlines are brought into the chamber from a compressor on the surface. The reliability of the air supply depends on the probability that separate redundant airlines will survive a mine disaster. Therefore, routings of the two (or more) airlines should be widely separated. Obviously the two airlines should not be run in the same entry. A possible example of separation is to bring one line underground from the closest portal while bringing a second line from the surface through a power borehole. The air pipes should be installed consistent with the successful practice for pipe (air or water) installation within the particular mine, taking into consideration stability of roof, ribs and floor.

*1983 dollars; see Foreward

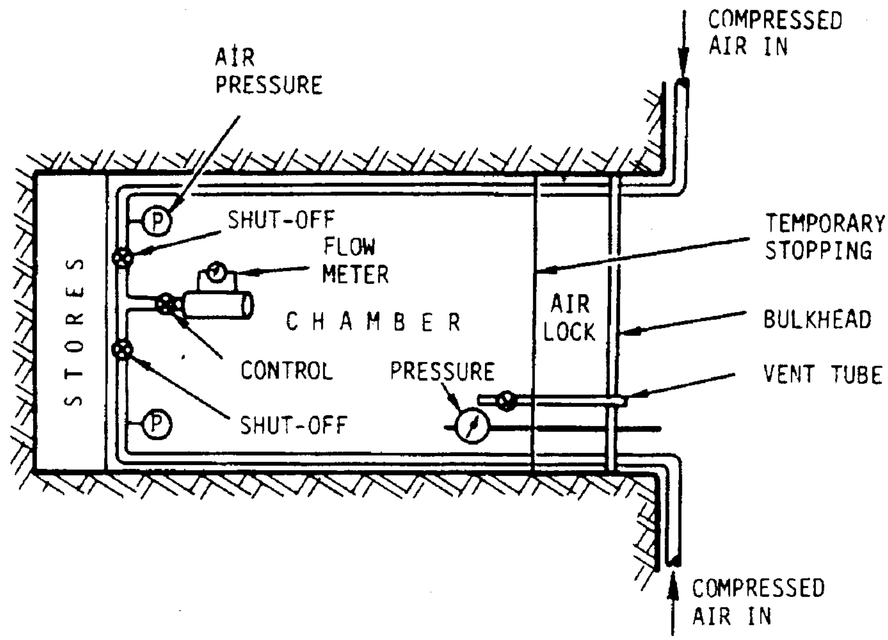
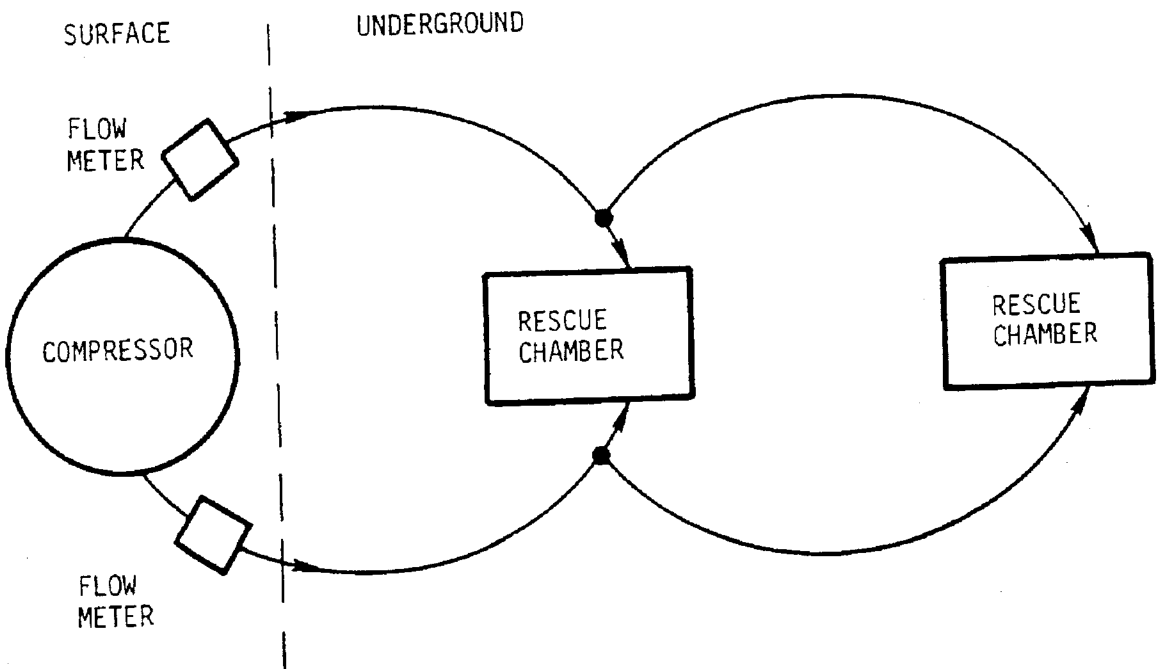


FIGURE 3. - Schematic of compressed airline rescue chamber.

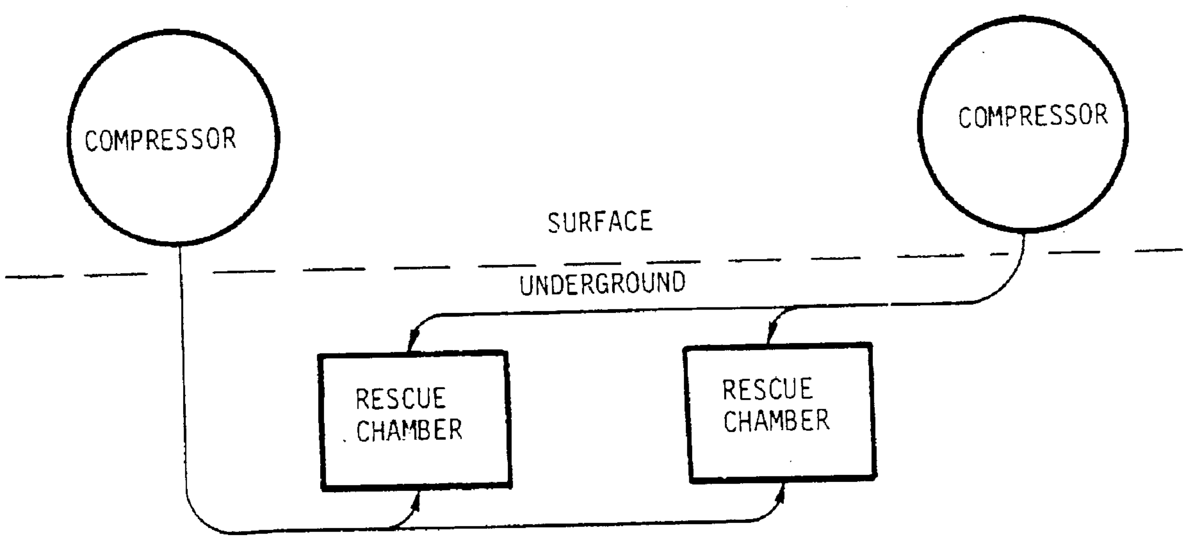
A pressure gauge should be installed on each airline as well as shutoff valves which can be closed individually if a broken airline occurs. The lines shall be tied together with a control valve and flowmeter at the pipe exit. The air outlet should be located as far as practical from the bulkhead in order to promote a cross flow of air in the chamber. A vent tube with a check valve and control valve must be installed through the bulkhead to permit sufficient air to leave the chamber. A differential pressure gauge must be installed to monitor the chamber overpressure.

Once installed, the system shall be tested with the chamber sealed. At design airflow, an overpressure of at least 5 in. of water must be achieved with the vent tube valve shut off. If this overpressure cannot be maintained, then areas of air leaks must be sought and sealed until 5 in. of water overpressure is achieved.

Either singular or multiple compressors may be used. Figure 4 a and b shows these approaches schematically. When a single



a) SINGLE COMPRESSOR SUPPLY



b) SEPARATE COMPRESSOR

FIGURE 4. - Singular and multiple compressors.

compressor is used, flowmeters must be installed in each branch line in order to detect line breaks. If the flow rate through a broken line is large enough to reduce supply pressure (overload the compressor), the flow in that branch must be reduced until the compressor can supply rated pressure. Compressors must be selected with reserved capacity (safety factor) of at least twice the flow required for the rescue chambers supplied by each line (for example, in Figure 3 the single compressor shown must have a capacity four times the demand of the sum of the two rescue chambers shown). Compressor supply pressures must be 100 $lb/in.^2$ at flow design capacity if the air supply is to be used for power in the chamber (see Section 5).

Airline pipe must be sized such that pressure drop is not excessive. Table 6 shows receiver pressures as a function of selected flows with a supply pressure of 100 $lb/in.^2$. Since rescue chamber power may be extracted from the compressed air flow, the pipe should be sized to provide approximately 90 $lb/in.^2$ or larger at the chamber. Except for very long or short airline, a 1-in. IPS pipe is suitable.

If it is assumed a pipeman and helper can install 300 ft of pipe/day* and the combined direct and indirect labor cost is $360**/day and if a typical 1-in. pipe price is $90/100 ft, then the installation cost of pipe/thousand ft is:

$$\frac{\$360}{300} \times 1000 \text{ ft} + \frac{\$90}{100 \text{ ft}} \times 1000 \text{ ft} = \$2{,}100/\text{thousand ft}$$

For typical installations, the cost of piping is the dominating cost. The cost of a compressor is likely to be less than $7000. An additional budget of $1400 should cover miscellaneous valves, flow meters, gauges, etc.

2.1.5.3 Air Supplied From Compressed Air Storage

If a situation exists where neither a borehole nor airlines can be installed, it is possible to construct a chamber with a self-contained air supply. As mentioned at the beginning of Section 2, a self-contained air supply system provides the least flexibility in terms of time available to achieve removal of the entrapped miners, and is definitely the highest cost to implement if significant man/days of air supply are provided. A reasonable

* 300 ft/day based on underground construction experience of FMA staff.
**1983 dollars; see Foreward.

TABLE 6. - Delivered pressure by pipe size

P_o, Receiver pressure ($lb/in.^2$) with supply pressure = 100 ($lb/in.^2$), air flow = 30 scfm

(28 ft^3/min minimum chamber flow)

Pipe Distance (L) (ft)	3/4 in. IPS ($lb/in.^2$)	1 in. IPS ($lb/in.^2$)	1-1/4 in. IPS ($lb/in.^2$)	1-1/2 in. IPS ($lb/in.^2$)
2,000	84	95	99	99
4,000	60	90	98	99
6,000	-	85	97	98
8,000	-	79	95	98
10,000	-	-	94	97
P_o =	$\sqrt{(100)^2 - 1.47L}$	$\sqrt{(100)^2 - 0.459L}$	$\sqrt{(100)^2 - 0.1119L}$	$\sqrt{(100)^2 - 0.0520L}$

P_o, Receiver pressure ($lb/in.^2$) with supply pressure = 100 ($lb/in.^2$), air flow = 60 scfm

Pipe Distance (L) (ft)	1 in. IPS ($lb/in.^2$)	1-1/4 in. IPS ($lb/in.^2$)	1-1/2 in. IPS ($lb/in.^2$)
2,000	81	96	98
4,000	57	91	96
6,000	-	86	94
8,000	-	81	92
10,000	-	76	90
P_o =	$\sqrt{(100)^2 - 1.67L}$	$\sqrt{(100)^2 - 0.419L}$	$\sqrt{(100)^2 - 0.190L}$

P_o, Receiver pressure ($lb/in.^2$) with supply pressure = 100 ($lb/in.^2$), air flow = 90 scfm

Pipe Distance (L) (ft)	1 in. IPS ($lb/in.^2$)	1-1/4 in. IPS ($lb/in.^2$)	1-1/2 in. IPS ($lb/in.^2$)
2,000	52	90	96
4,000	-	80	92
6,000	-	68	87
8,000	-	-	82
10,000	-	-	77
P_o =	$\sqrt{(100)^2 - 3.66L}$	$\sqrt{(100)^2 - 0.898L}$	$\sqrt{(100)^2 - 0.900L}$

Equivalent pipelength per standard elbow

IPS (in.)	Equivalent Length (in.)
3/4	1.2
1	1.6
1-1/4	2.2
1-1/2	2.6

Data adapted from Compressed Air and Gas Handbook, Compressed Air and Gas Institute, N.Y., 1973 design time for rescuers to reach entrapped miners is 2 weeks via drilling an escape shaft (5). Only if a reasonable alternative plan exists which offers a shorter rescue time can a chamber air supply be designed for less than 14 days. If a plan exists and a shorter design time is used, the air supply must be sized to provide at least 2 days more air supply than the period of the plan. For example, if a plan exists where removal of an entrapped miner is expected in 1 day, then a 3-day supply of air must be provided.

The regulation of the release of air into the chamber should be similar to that for an airline air supplied chamber (see Figure 3) incorporating the following features:

a. Flowmeter

b. Cross flow

c. Vent tube

d. Differential pressure gauge to measure chamber over prssure.

Additionally, a pressure regulator(s) shall be installed such that the air delivery pressure from the air storage is 90 to 100 $lb/in.^2$.

In Appendix D, cost and size of a typical compressed air system are developed. A cost of about $2400 to $2800/man/day is expected with air tank storage volume of about 22 to 16 ft^3/man/day.

2.1.6 Technological Developments

The potential for technical developments in life support systems for self-contained chambers exists. Life support technology for aerospace vehicles and submarines has advanced well beyond the brute force techniques of stored compressed air. There are, however, significant differences between underground rescue chamber characteristics and the other systems. Particularly significant is that rescue chambers have long standby times and their use is unscheduled (no time immediate to the mission for preparation). The energy available for the operation of life support equipment such as fans and controls is severely limited. Recent developments of oxygen self-rescuers based on the liberation of oxygen from solid KO_2 which requires no mechanical driving power, offer some hope that the solid chemical approach could be developed for self-contained rescue chambers which would reduce cost to a tolerable level (lower than borehole cost). A particular technical problem is the prevention or elimination of hazardous gases which can be forced into the chamber. Until the development and successful demonstration of such a system is achieved, such approaches are not recommended; hence they are outside these guidelines.

2.2 Guidelines for Atmospheric Life Support

2.2.1 Method

The atmospheric life support system of any rescue chamber shall be of a forced air type. Three methods of supplying air are covered by these guidelines:

a. Air forced from the surface through a borehole directly connected to a rescue chamber

b. Compressed air forced from a surface compressor(s) through redundant (two or more) airlines to the rescue chamber

c. Compressed air stored as part of the rescue chamber underground (self-contained).

Discussion of each type is given previously in subsection 2.1.5.

2.2.2 Air Flow Requirements

The design air flow to each chamber shall be at least 28 scfm or 1.9 scfm/man times the number of men contained in the chamber, whichever is the larger value. This flow shall be achieved with the chamber pressurized to at least 5 in. of water gauge greater than the mine just outside the chamber. For chambers with stored compressed air, this flow rate shall be maintained for at least 14 days unless a reasonable plan exists for removing the entrapped miners in a shorter period. For cases with such a plan, the above specified air flow rate shall be maintained for at least 2 days longer than the time expected in the plan.

2.2.3 Air Flow Instrumentation

A flowmeter(s) shall be installed within the chamber to monitor the flow of breathing air (see subsection 2.1.5). A differential pressure gauge shall be installed within the chamber such that chamber pressure relative to the outside mine may be monitored.

2.2.4 Soda Lime

A sealed store of soda lime shall be provided for emergency absorption of CO_2 (see subsection 2.1.3). The store shall be sufficient for 14 days or 196 lb/person (capacity of chamber). Gloves shall be provided for the handling of the soda lime.

2.2.5 Testing

On completion of a chamber installation the air flow performance shall be tested to ensure that flows and pressures are equal to, or better than design requirements. Any deficiency in performance shall be rectified. Retesting shall be performed semiannually. If compressed air storage is used, the air capacity shall be checked every 90 days with any deficiency in capacity replaced.

2.2.6 Training

All miners likely to use the chamber shall be instructed in the startup and operation of the breathing air system including the use of a passive soda lime pad in the event that CO_2 concentration exceeds 1 percent (see subsection 2.1.3). This training shall include the measurement of gas concentrations using gas detection tube apparatus.

Within the chamber, instructional information for the breathing air system including graphic (pictorial schematic) displays shall be posted. During training, the instructional information shall be used. The information presented shall include at least the following:

a. Air flow schematic

b. Location of the valves, pressure regulators, gauges, air tanks, and routing of airlines through the mine

c. Listing of readings (calibrated) for the setting of flows and pressures

d. Directions for making and using a soda lime CO_2 scrubber

e. Directions for air flow and chamber pressure control.

3. CONFIGURATION AND CONSTRUCTION

This section discusses the factors pertinent to the configuration and construction of rescue chambers. These discussions provide the background and reasoning for the guidelines which are formulated in the final subsection of this section.

3.1 Technical Discussion

The major factors which should be considered during the design and construction of rescue chambers are:

a. Size and area requirements of rescue chambers

b. Configuration and construction of bulkheads

c. Roof support requirements for rescue chambers.

These factors are elaborated on in the following subsections.

3.1.1 Size and Area Requirements

A rescue chamber is implemented by sealing off both ends of a crosscut or the front end of a dead heading with explosion-proof bulkheads. The space between the bulkheads (or between bulkhead and dead end) is used as shelter and is equipped with emergency provisions capable of sustaining trapped miners for several days.

Before the construction of bulkheads is initiated, an accurate estimate must be made of the space the bulkheads must enclose. This space or internal volume must be sufficient for:

a. Storing emergency supplies and equipment

b. Comfort of persons using the chamber

c. Construction of air locks.

Since the cross-section of the rescue chamber can be considered to be constant, an estimate of the length of the crosscut to be enclosed by the bulkheads must be made to satisfy the above requirements.

3.1.1.1 Requirement of Storing Emergency Supplies and Equipment

Emergency supplies and equipment are planned to be stored at the back of the chamber. Section 6 provides a detailed list of equipment and supplies that must be permanently maintained and stored in the rescue chamber. The volume required to store food, water, bunks (folded), self-rescuers, first aid supplies and other sundry materials would be about 105 ft^3 maximum. For an 18 × 6 ft crosscut this would require 1 ft of the length of the crosscut to store the necessary supplies and equipment.

Table 7 summarizes the volume requirements of equipment and supplies to be stored in the chamber.

3.1.1.2 Requirements for Comfort

The space requirements for persons in the shelter are estimated on the basis of 15 ft^2*/person. For 15 persons, this would necessitate at least 225 ft^2 or 12.5 ft length of a crosscut 18 ft wide.

TABLE 7. - Summary of estimated volume for equipment and supplies

Item	Total Volume ft^3	Volume/Person ft^3/person
Food	35	2.30
Water	20	1.33
15 Self Rescuers	10	0.67
2 First Aid Kits	8	0.50
15 Bunks (folded)	30	2.00
Sundry Materials	1	
Gas Detector Tubes, Pumps	1	
Total	105	6.80

*Based on civil defense space allowances(11).

3.1.1.3 Space Requirements for Airlocks

Once the chamber has been occupied during an emergency, it is advisable to construct a second, temporary stopping inside the explosion-proof bulkhead in order to create an airlock. This will minimize the risk of the chamber atmosphere being contaminated by mine air if persons enter or leave the chamber subsequent to its original occupation.

This stopping would be constructed of wooden framing and brattice material stored in the chamber. It may be desirable to construct the frame beforehand.

The temporary stopping should be spaced a minimum of 2 ft from the bulkhead. If there is a bulkhead with a door at each end of the chamber, an airlock must be built for each end. Thus, either 2 or 4 ft of chamber length must be allowed for airlocks.

3.1.2 Configuration and Construction of Bulkheads

Three different explosion-proof bulkheads for refuge chambers have been designed, fabricated and successfully tested under USBM Contract (3). All three designs featured modular, prefabricated metal panels which could be reused. The type of panels and methods of attachment were different in each design in order to provide systems which could adapt to the broadest possible range of coal mining conditions in the United States. The three basic designs were as follows:

a. *Channel-Turnbuckle Bulkhead* (Figure 5). This design utilizes roof bolt and footing box anchorage and is used in mines where the roof and floor are both competent. The bulkhead components consist of off-the-shelf aluminum channel members (12 in. wide × 5 in. flange × 5 ft long), roof bolts (1-1/2 diam × 24 in.) with turnbuckles, and footing boxes. The channel members are arranged back-to-back for height adjustment. The lower channel is anchored in a footing box which is grouted in place in a trench excavated into the mine floor. The upper channel is connected to a third channel bolted flat against the mine roof and further anchored by connection through a turnbuckle to a 1-1/2 diam roof bolt.

   These assemblies bolt together, flange-to-flange, to form a bulkhead in 1 ft increments for crosscuts of any width. The height limitation from the bottom of the footing box in the trench to the top of the roof channel is from 6 ft 1-1/2 in. to 7 ft 1-1/2 in.

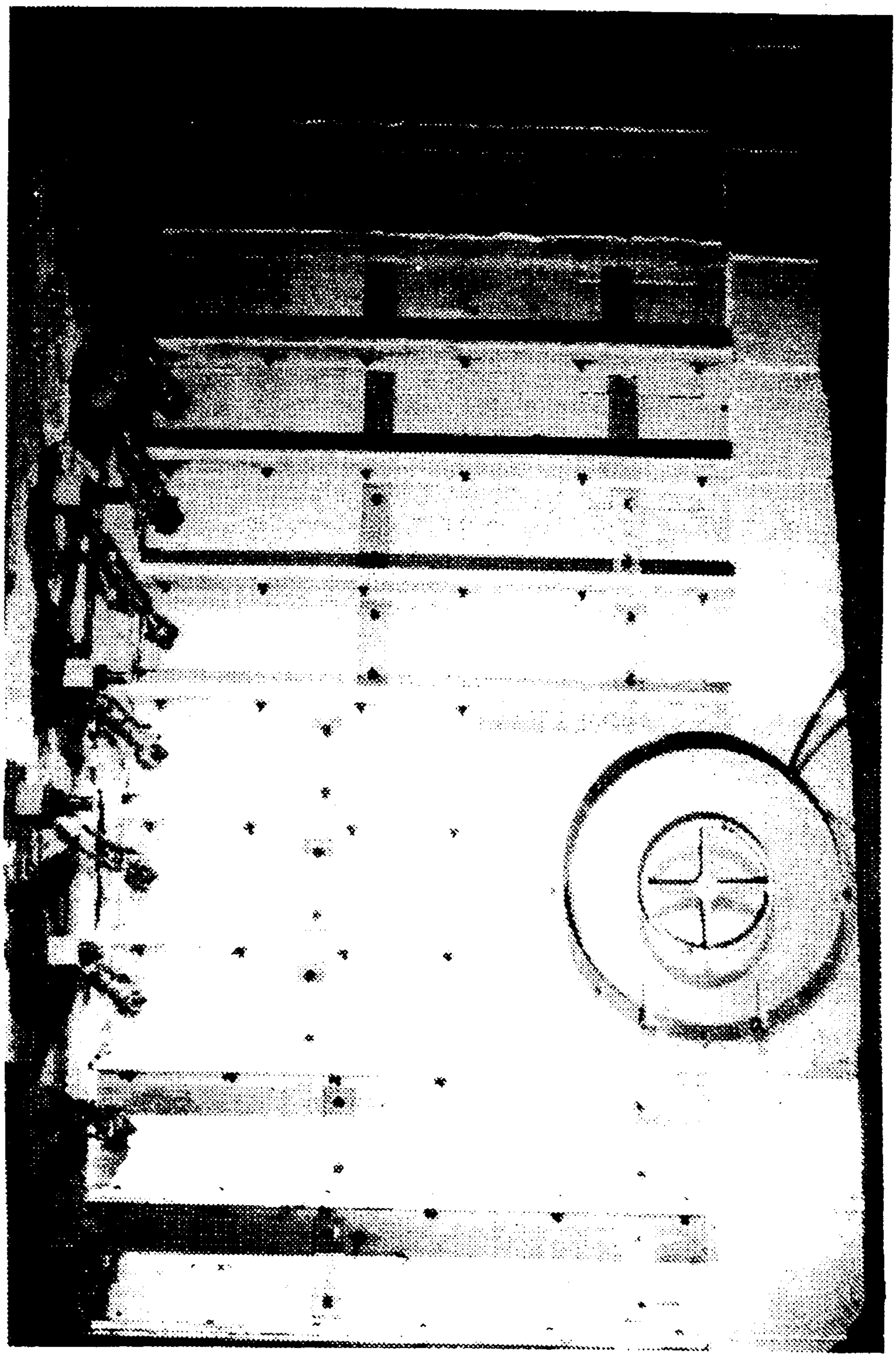


FIGURE 5. - Channel-turnbuckle bulkhead.

b. *Truss Bulkhead* (Figure 6). This design transmits the explosion forces into the floor alone and is used in mines where the floor is competent rock but the roof is weak. The pinholes in the roof only resist negative pressure to prevent overturning. The main components of this bulkhead are 4 × 8 steel box beam posts with sliders that fit inside at the top for height adjustment. These posts fasten at the bottom to footing boxes which are grouted in place in a trench excavated into the mine floor. Connected near the top of the posts to the rear are large angle struts which transmit force down to a second set of footing boxes 5-1/2 in. behind the front set. Horizontal ties at the bottom complete a triangle to stabilize the posts and angle struts. Decking assemblies of high strength corrugated steel and 2 in. box beams attach to the front of the posts. A door also attaches.

The bulkhead width is adjustable in increments of 27 in. for crosscuts of any width. The height limitation from the bottom of the footing boxes in the trench to the mine roof is from 6 to 7 ft. This includes 2 in. of clearance at the top for the urethane foam seal.

c. *Arch Bulkhead* (Figure 7). Here explosion forces are transmitted to the rib coal walls of a crosscut; this design is used in mines where both the roof and floor conditions are poor. This bulkhead is a 17 ft radius tunnel-lining often found in subway or other tunnels, but turned on its side and broken down into components of a weight two men can handle. The liner plates are 2 ft wide (high) by either 3 ft or 1-1/2 ft long. The structural members are 6 in. H beam ribs, either 3 ft or 4-1/2 ft in length. Most mine openings up to 20 ft can be accommodated by various combinations of ribs and liner plates in increments of half plates (1-1/2 ft). Maximum width bulkhead is 20 ft-10 in. across. The height is 6 ft-11 in. including 2 in. of clearance at the bottom and 2 in. at the top for the seal. A layer of liner plates can be omitted for a bulkhead height of 4 ft-11 in.

Reinforced concrete abutments in the rib coal spread the reaction forces.

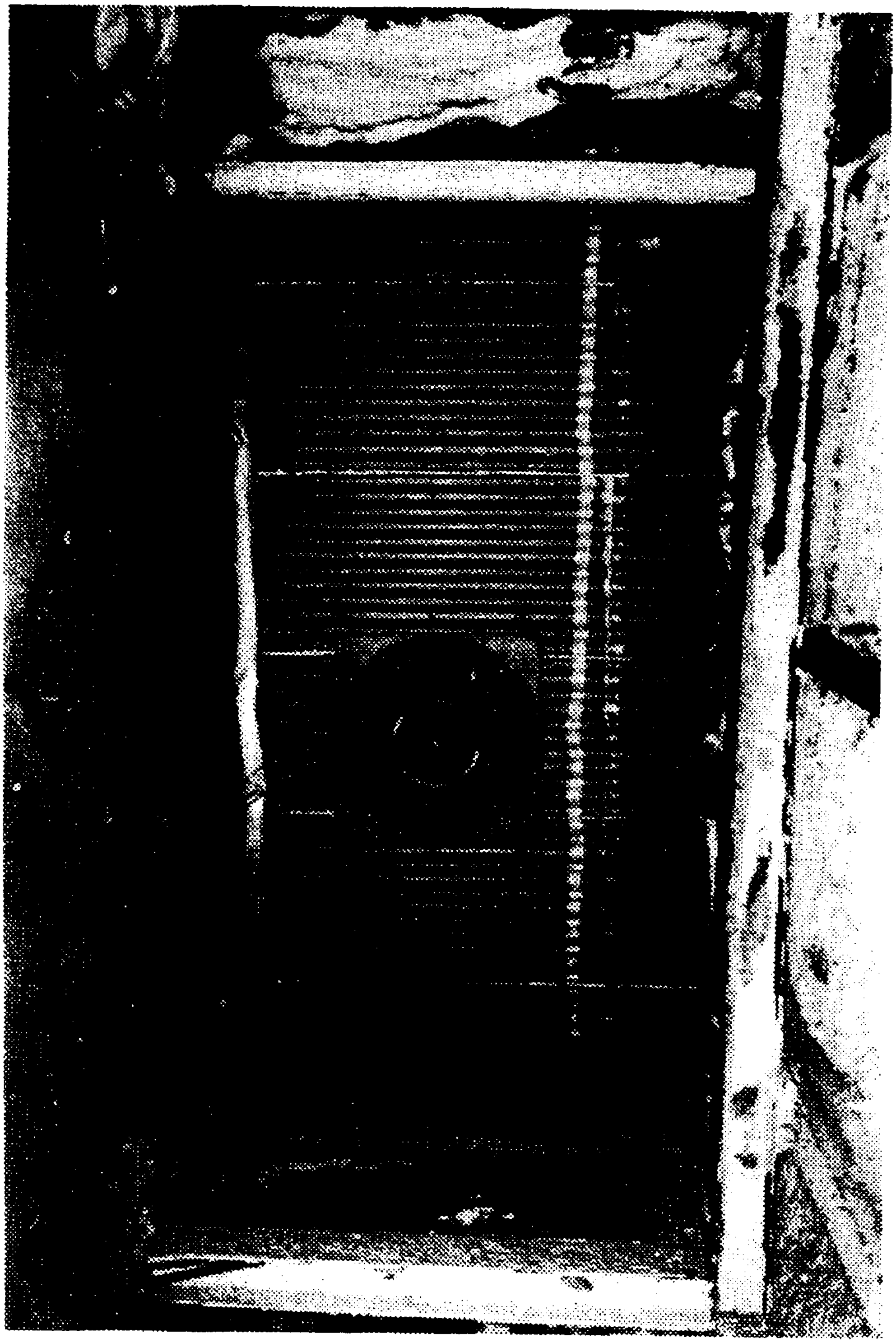


FIGURE 6. - Truss bulkhead.

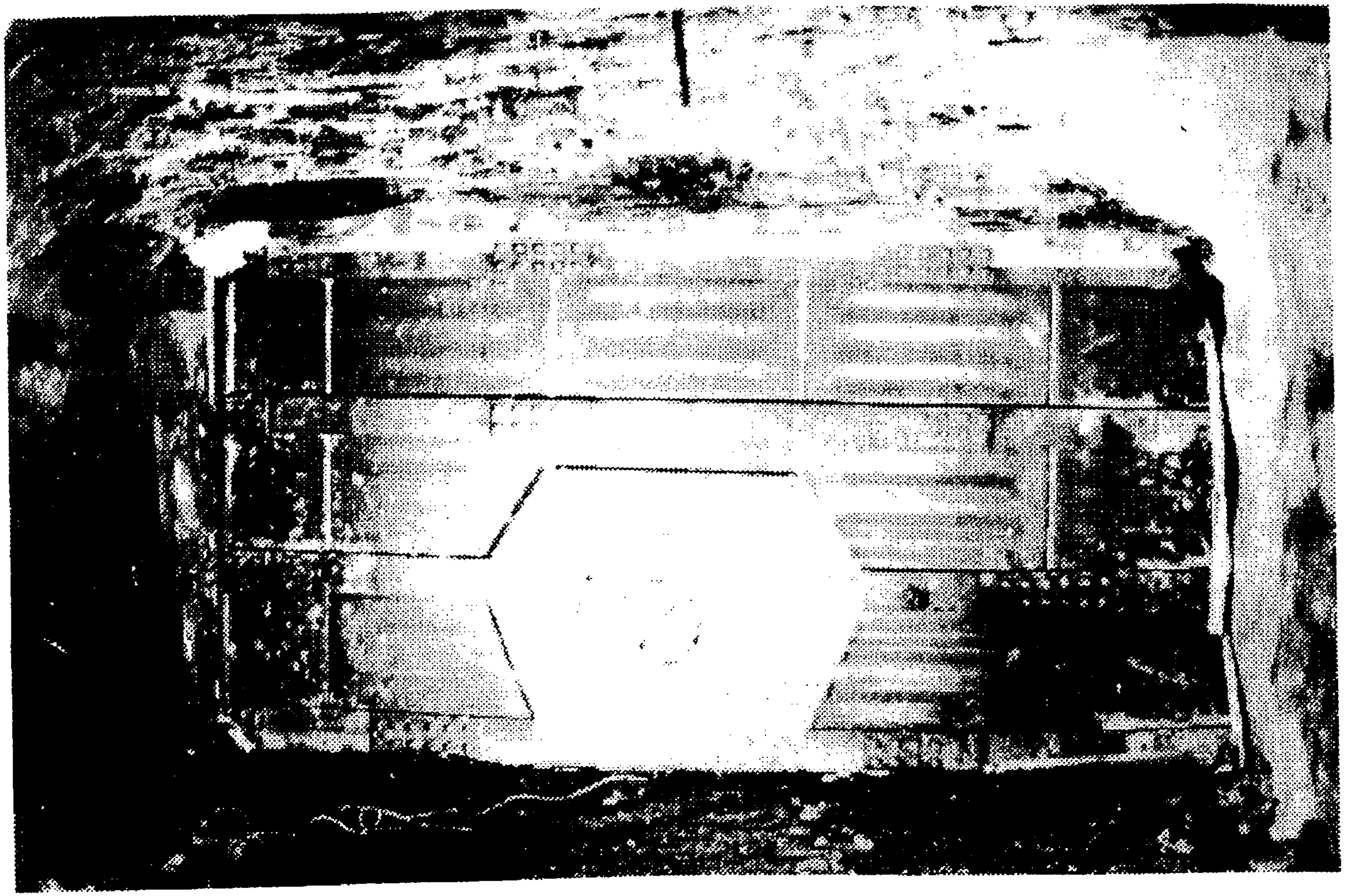


FIGURE 7. - Arch bulkhead

Sealing to the mine opening around the periphery of all three bulkheads is accomplished with urethane foam and thin gauge aluminum flashing bent in such a way it will flex rather than break when a shock wave moves the bulkhead. Internal joints in the bulkheads are sealed with silicone rubber sealant.

3.1.3 Roof Support

It is essential that the roof of a rescue chamber remain stable during the life of the chamber. *Sloughing* of roof may occur particularly if the stratum is sensitive to moisture. It is advisable that the roof be treated with a mine sealant to prevent deterioration of roof rock when this problem may be anticipated.

Minimum requirements for West German coal mines indicate that the area where rescue chambers are erected should be shotcreted (9). Shotcreting not only seals the chamber but provides some roof support.

Although the roof of the refuge chamber will already have been bolted, additional roof support should be considered whenever the refuge chamber is scheduled to remain in place for a long time.

The different kinds of support that can be considered are:

a. Wire mesh

b. Steel beams or rails

c. Steel or timber sets

d. Steel arches

3.1.3.1 Wire Mesh

In many mines, the roof is reinforced by roof bolts and wire mesh. The mesh is normally extended across the roof and down the rib from 6 to 18 in. Cement-sand mortar, often referred to as "gunite," usually is applied as a 2 to 3 in. layer, to prevent weathering of roof rock.

3.1.3.2 Steel Beams or Rails

Steel beams or rails supported by concrete block walls can provide excellent protection of both roof and ribs in a refuge chamber. This method of support is presently being used in an installed chamber in Pennsylvania. Figure 8 shows a support

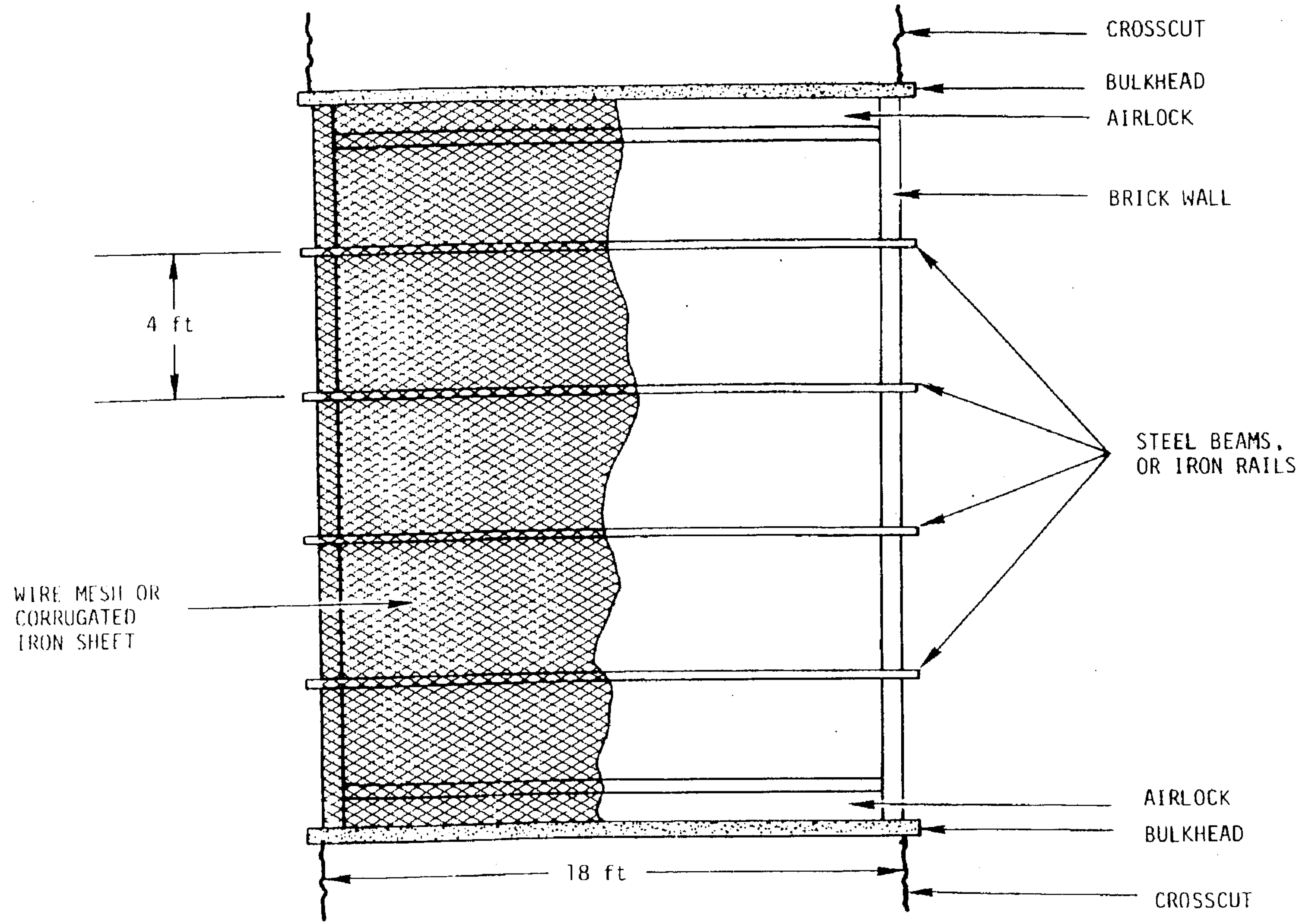


FIGURE 8. - Support plan for rescue chamber using steel beams or rails with wire mesh or corrugated iron sheet.

plan for the rescue chamber using this form of support. Wire mesh, as described earlier, can be used to prevent the entry of roof rock into the chamber. In the Pennsylvania mine, corrugated sheets were placed on top of the rails because of the presence of combustible material overlying the seam.

3.1.3.3 Steel or Timber Sets

The simplest timber set consists of a crossbar, cap or header supported on two upright posts, as shown in Figures 9 and 10. This type of roof support is similar to the use of cinder block and headers described in the previous subsection, except that the posts do not provide much protection from rib sloughing. Where this is a problem, it might be desirable to place corrugated sheet behind the posts.

3.1.3.4 Steel Arches

In cases where movement of the roof is expected, yieldable steel arches can be used (Figure 11). Generally, three U-shaped arched segments are overlapped to provide a large area of contact at the yielding joints, which are clamped to provide resistance to yielding. Although they are high in initial cost,

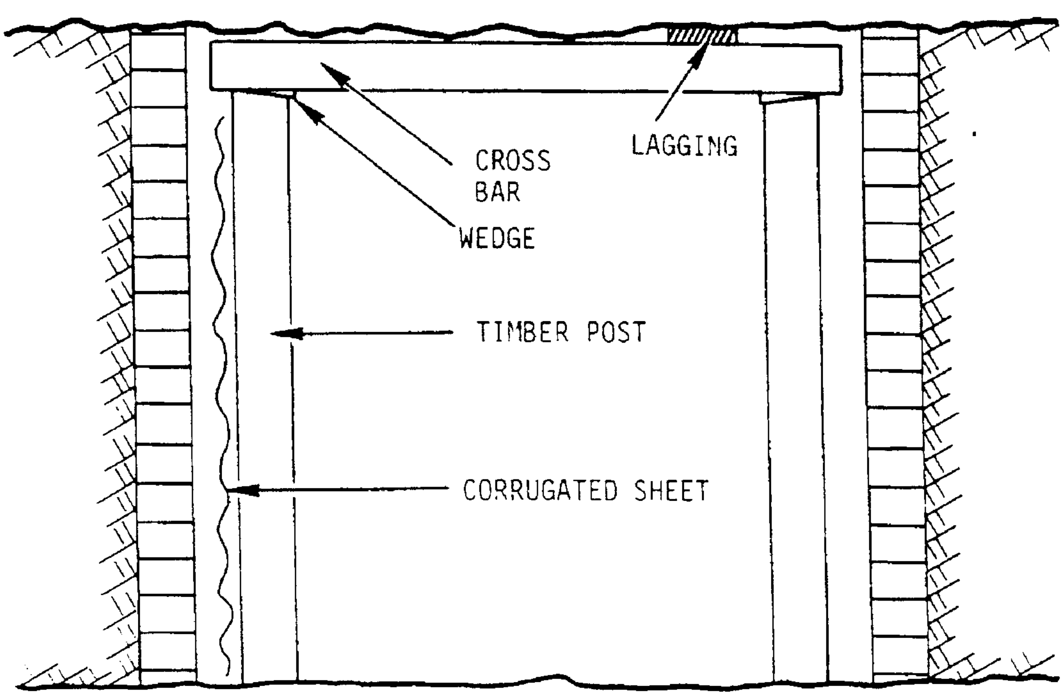


FIGURE 9. - Timber set.

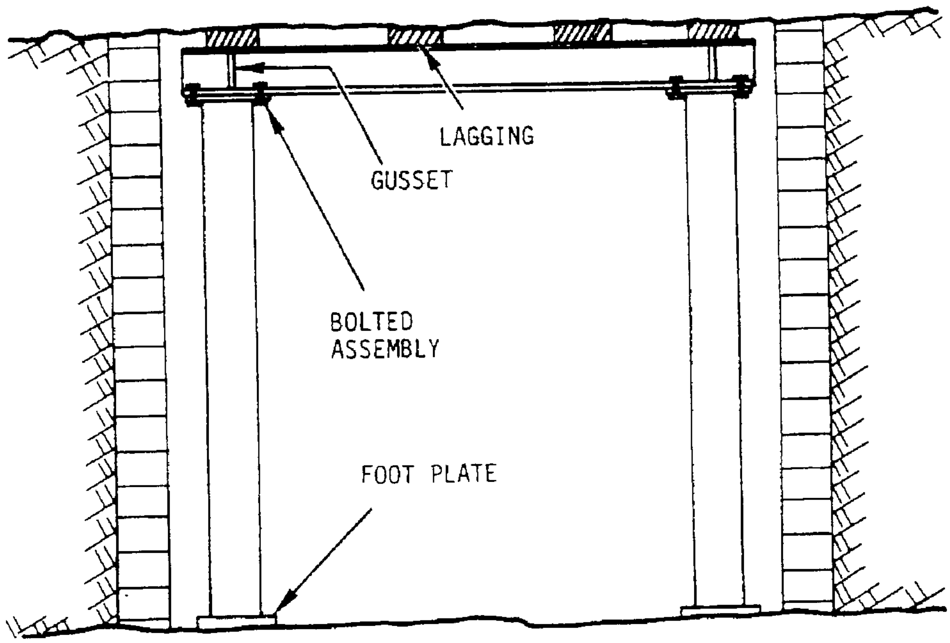


FIGURE 10.- Steel set support.

yieldable steel arches provide dependable, long, maintenance-free service. The arches can be spaced 4 ft apart to provide high support density. Yieldable arches are used under severe conditions where extensive movements can occur due to the presence of faulted ground or in areas of subsidence.

Rigid steel arches have been used for support of permanent mine entries. In coal mines, two-piece rigid arches are usually used. Tie rods are used with either type of arches for lateral stability. All voids between the arch structure and roof should be thoroughly backfilled.

3.1.3.5 Selection of Supports

The proper selection of a support requires the consideration of:

a. Magnitude and type of forces expected on the support after installation

b. The amount of roof and bottom convergence anticipated at the site

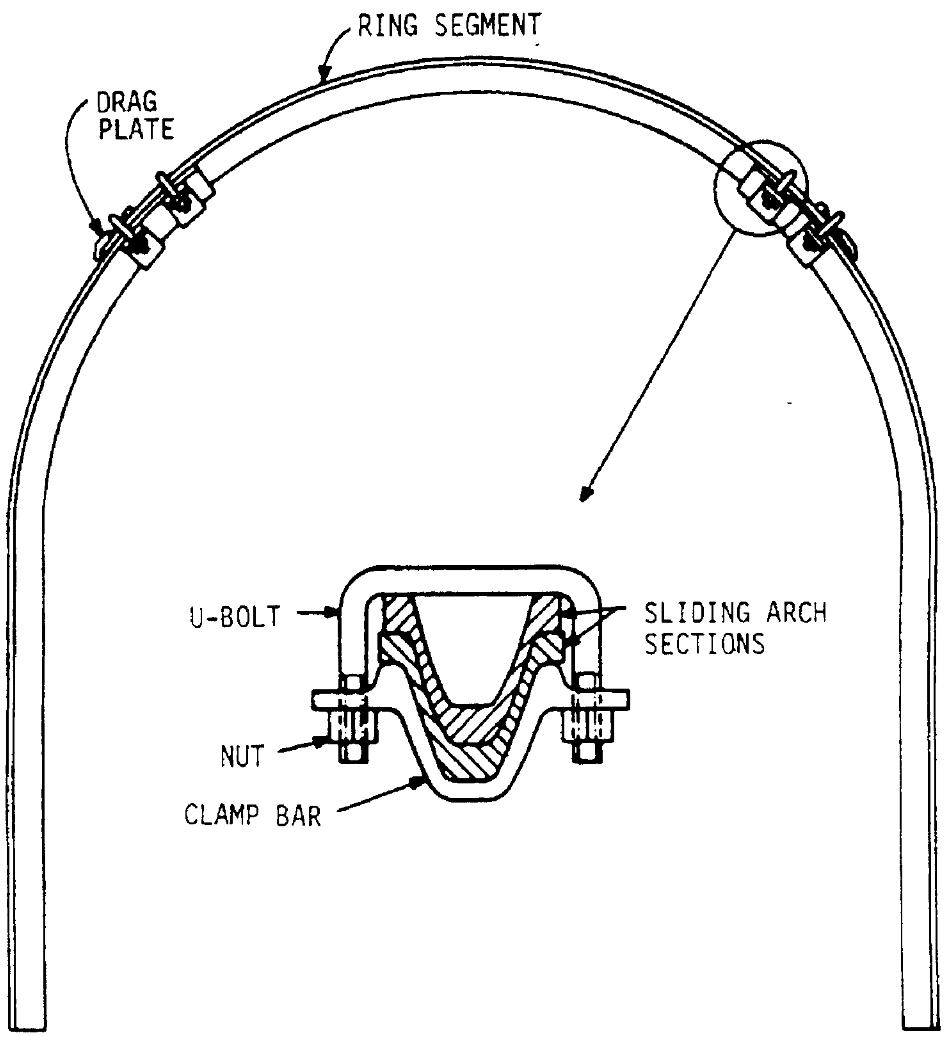


FIGURE 11. - Yieldable arch structure.

c. How permanent the opening and thus the support must be

d. Environmental conditions to which the support will be subjected

e. Economic factors consistent with safety.

Support costs are shown in Table 8.

3.1.3.6 Standby Ventilation

During standby periods methane may build up in the chamber or the atmosphere may become oxygen-deficient. To preclude this the chamber must be ventilated during standby periods.

For borehole-connected chambers, a small amount of "leakage" should be permitted through the borehole. Other types of chambers require other means. A West German approach is shown schematically in Figure 12 (9). In some cases a small fan may be needed.

3.2 Guidelines for Configuration and Construction

The following are guidelines for configuration and construction:

a. All rescue chambers shall be of adequate size and area to provide:

   1. Sufficient space for storing emergency supplies and equipment

   2. Sufficient space (minimum of 15 ft^2/person) for the comfort of individual miners.

TABLE 8. - Comparative support costs

Type	Direct Cost* $/linear ft of Rescue Chamber	Cost/Person
Wire mesh	50-70	67-93
I-beams	140	186
Used rails	70	93
Steel arches	180	240

*Direct cost includes only material and labor costs, in 1983 dollars.

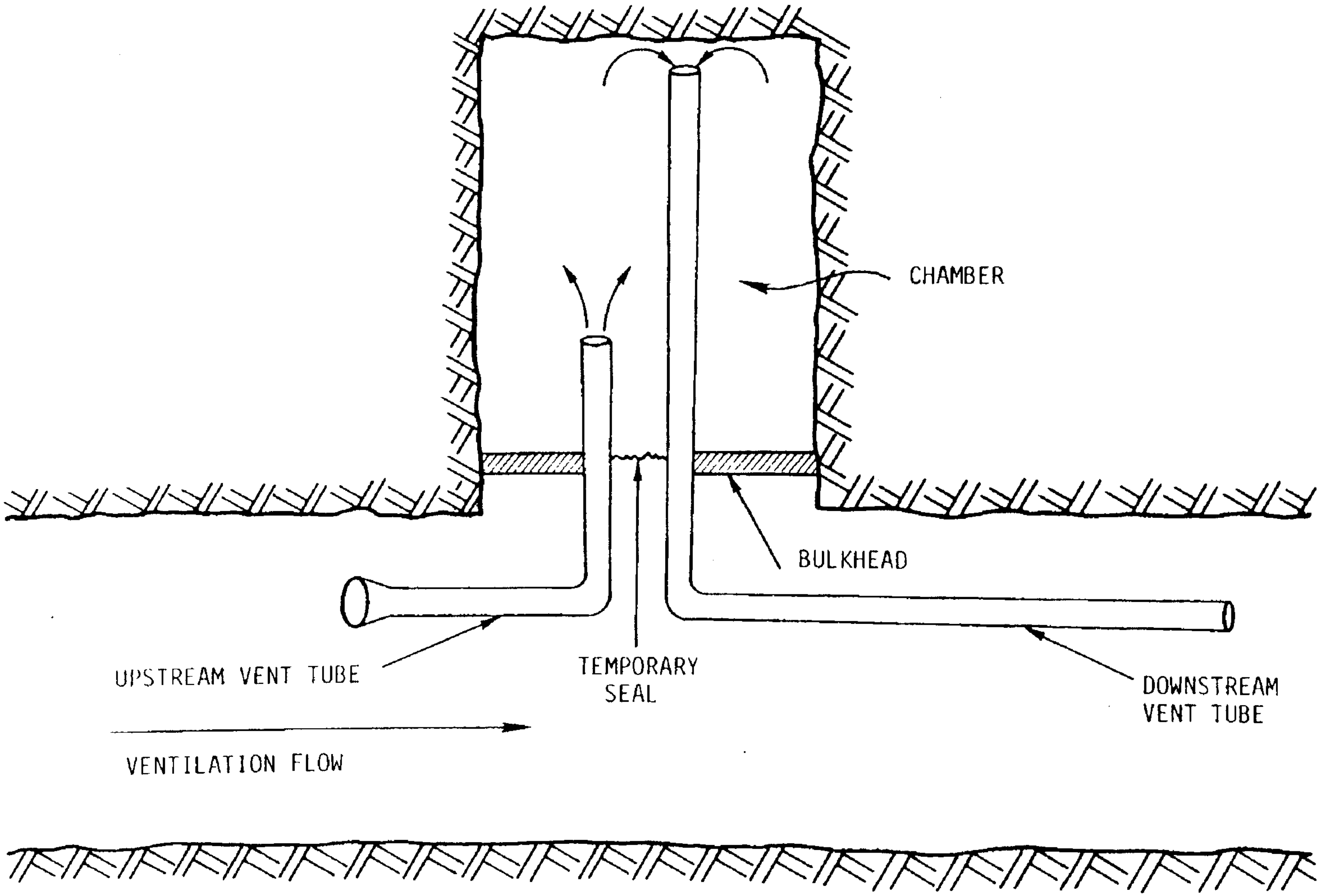


FIGURE 12. - Schematic of standby rescue chamber ventilation.

b. All rescue chambers shall have airlocks located inby the rescue chamber from the bulkhead(s). The airlock(s) in the rescue chamber shall be constructed by erecting a temporary stopping(s) with materials stocked in the chamber. The stopping(s) shall be adequately sealed against the ribs, floor, and roof of the entry.

c. All rescue chambers shall have appropriate explosion-proof bulkheads, compatible with underground conditions.

d. The walls of the rescue chamber shall be lined with a minimum one-brick thick wall.

e. All rescue chambers shall be adequately supported by artifical means for the entire life period of the chamber.

    1. Where roof bolting is the only method of permanent roof support, the applicable criteria in 30 CFR 75.200-7 (a), (b), (c) and (d) of the Full Roof Bolting Plan shall apply.

    2. Where roof bolting may be inadequate or insufficient, all rescue chambers shall be supported by adequate additional or alternative artificial means.

f. Other measures as may be necessary depending on local conditions shall be installed to safeguard the lines of persons seeking refuge in the chamber.

g. The rescue chamber must be maintained in such a manner that it is well-ventilated with fresh air when not in use.

4. CHAMBER LOCATION GUIDELINES

4.1 Discussion

4.1.1 Introduction

The purpose of this subsection is to provide guidelines for the location of rescue chambers that will be applicable, at least in a general way, to most underground coal mines. It is impossible to anticipate every possible variation in circumstances; the guidelines will no doubt have to be modified according to the judgment of the individuals most familiar with each situation. The reasoning behind the guidelines is provided so as to aid such individuals in their decisions.

The application of the chamber location guidelines to five actual working coal mines is presented as Appendix E. Included is a cost comparison of borehole and compressed air life support systems for each.

4.1.2 Background

The Secretary or an authorized representative of the Secretary may prescribe in any coal mine that rescue chambers, properly sealed and ventilated, be erected at suitable locations in the mine to which persons may go in case of an emergency for protection against hazards. Such chambers shall be properly equipped with first aid materials, an adequate supply of air and self-contained breathing equipment, an independent communication system to the surface, and proper accommodations for the persons while awaiting rescue, and such other equipment as the Secretary may require. A plan for the erection, maintenance, and revisions of such chambers and the training of the miners in their proper use shall be submitted by the operator to the Secretary for his approval.

Previous work on the doctrine of rescue chamber location consists of FMA's report on the design of reuseable explosion-proof bulkheads (3), and a study of rescue shelters by Ward, et al. (6), of the Pittsburgh Technical Support Center of MSHA.

The FMA report makes a distinction between temporary and permanent shelters, and proposes that temporary shelters be maintained within a maximum distance of each face, based on seam height, and that permanent shelters be maintained at the mouth of each working section. This scheme results in a very large number of rescue chambers, which certainly are not all required.

The Ward report discusses four basic options for chamber location:

a. In the immediate face area on each section

b. At some maximum distance from the face

c. At the mouth of each section

d. At miscellaneous sites selected on a mine-by-mine basis.

The first two options are rejected by Ward for the following reasons:

a. Miners may be tempted to remain in the chambers, inby a fire, unnecessarily

b. Borehole access from the surface is not assured

c. Frequent moves of the chamber are not conducive to proper construction and maintenance

d. The hazard of inundation.

The third option, the mouth of each section, is considered to have advantages over the first two in being more permanent and being accessible to persons other than the face crew. It has the same disadvantage of all guidelines based on arbitrary location according to mine layout in that access from the surface is not assured.

Ward considers the fourth option, miscellaneous sites selected on a mine-by-mine basis, to be applicable to special situations such as some older mines where it is not possible to provide two independent escapeways for each section. This option most closely follows the letter of the rescue chamber regulation. It is this option that also most closely resembles the location guidelines as developed for this analysis, as explained in the following subsection.

4.1.3 Location Rationale

The guidelines for the location of rescue chambers as described in this subsection derive from the concept of the rescue chamber as a "second chance." Evacuation must remain the primary means of rescue in any emergency.

A rescue chamber must be located so as to provide a realistic "second chance" when it has become apparent that escape through both escapeways is impossible, without enticing a person to enter the chamber unnecessarily when evacuation is still viable.

The above concept implies three basic criteria of chamber location:

a. It must be located in the same direction from the working face(s) as the escape route.

b. It must be readily accessible from both escapeways.

c. It must be within 1 hr of foot travel of the face areas it is to protect. This assumes that miners have access to a 1 hr O_2 or filter self-rescuer.

A rescue chamber can be provided with life support either through a borehole to the surface or by an underground compressed air line. The former is supericr to the latter because of the airlines susceptibility to damage during an emergency. This implies a fourth basic criterion of rescue chamber location - accessibility of the surface above the chamber.

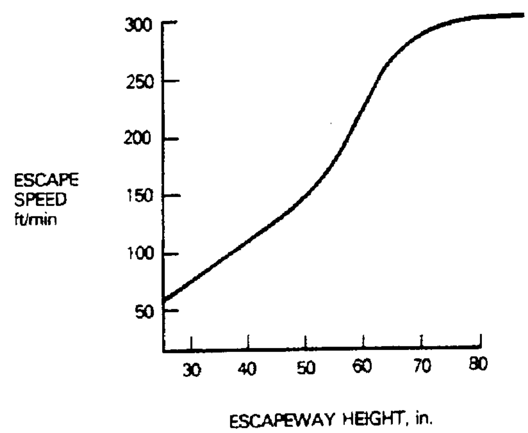
A consideration in some mines will be the problem of flooding. The rescue chambers are designed to sustain life for two weeks; a chamber should not be located in a structural low point that is likely to flood within that time should pumping stop.

If a crosscut chamber is to be used, a final requirement is that the chamber not be located between an intake and a return, in order to preclude a pressure differential across the chamber that would cause mine air to enter the chamber.

4.2 Location Guidelines

The selection of a location for a rescue chamber at a particular mine should proceed from the general to the specific along the following lines:

a. Using the mine map, identify working faces that are more than 1 hr from the surface by escapeway, on foot, (travel distances shown in Figure 13).



NOTE: DECREASE SPEED BY 15 PERCENT IF USING A SELF-RESCUER. DECREASE SPEED BY 10 PERCENT FOR POOR TRAVEL CONDITIONS (LOOSE GROUND, POOLS OF WATER).

FIGURE 13. - Average escape speeds in an underground coal mine.

Reference: Berry, et al, Recommended Guidelines for Oxygen Self-Rescuers, Vol. III - Escape Time Studies, USBM Contract Report No. J0199118, June, 1983.

b. Place the following information on overlays:

1. Intake and return escape routes, starting at each face from (a) above, for a distance equal to 1 hr of travel

2. Areas on the surface where physical and legal conditions permit the drilling of a borehole and installation of the borehole surface facilities

3. Areas of the mine that can be expected to flood within two weeks if pumping stops.

By superimposing the overlays, the areas that may be suitable for a rescue chamber are made readily descernable. These are the areas in which escapeways from several, prefereably all, of the sections to be protected are contiguous, and which are overlaid by surface conditions suitable for boreholes and are outside the 2-week flood zone.

The candidate areas can now be further narrowed down by keeping in mind the following guidelines, as mentioned earlier:

a. Locate the chamber where intake and return escapeways are close together, and where the chamber is readily accessible from either.

b. Locate the chamber so that as few persons as possible must, at any point, travel in a direction away from the portal in order to reach the chamber.

Intersections of entry systems naturally attract attention as satisfying the above requirements. Location of man-doors in stoppings should also be considered in order to place chambers at locations accessible from different airways.

A further consideration is that crosscut chambers be constructed only between two intakes or two returns, so as to prevent differential ventilation pressure from forcing mine air into the chamber.

In many cases, of course, it will not be possible to satisfy all of the requirements of an ideal chamber location, so that trade-offs will have to be made among the various criteria. In this situation, priority should be given to obtaining a site for a borehole. If the chamber cannot be located adjacent to an escapeway, directions to the chamber should be clearly posted in all escapeways. A chamber could also be located a short distance off the escape route to the surface if the way to the chamber and the way back to the escape route is clearly marked.

If it is *not* possible to obtain a site for a borehole, then air must be supplied by a compressed air line, and the chamber can be located according to the in-mine access guidelines.

Chamber location guidelines are summarized in the logic diagram shown in Figure 14.

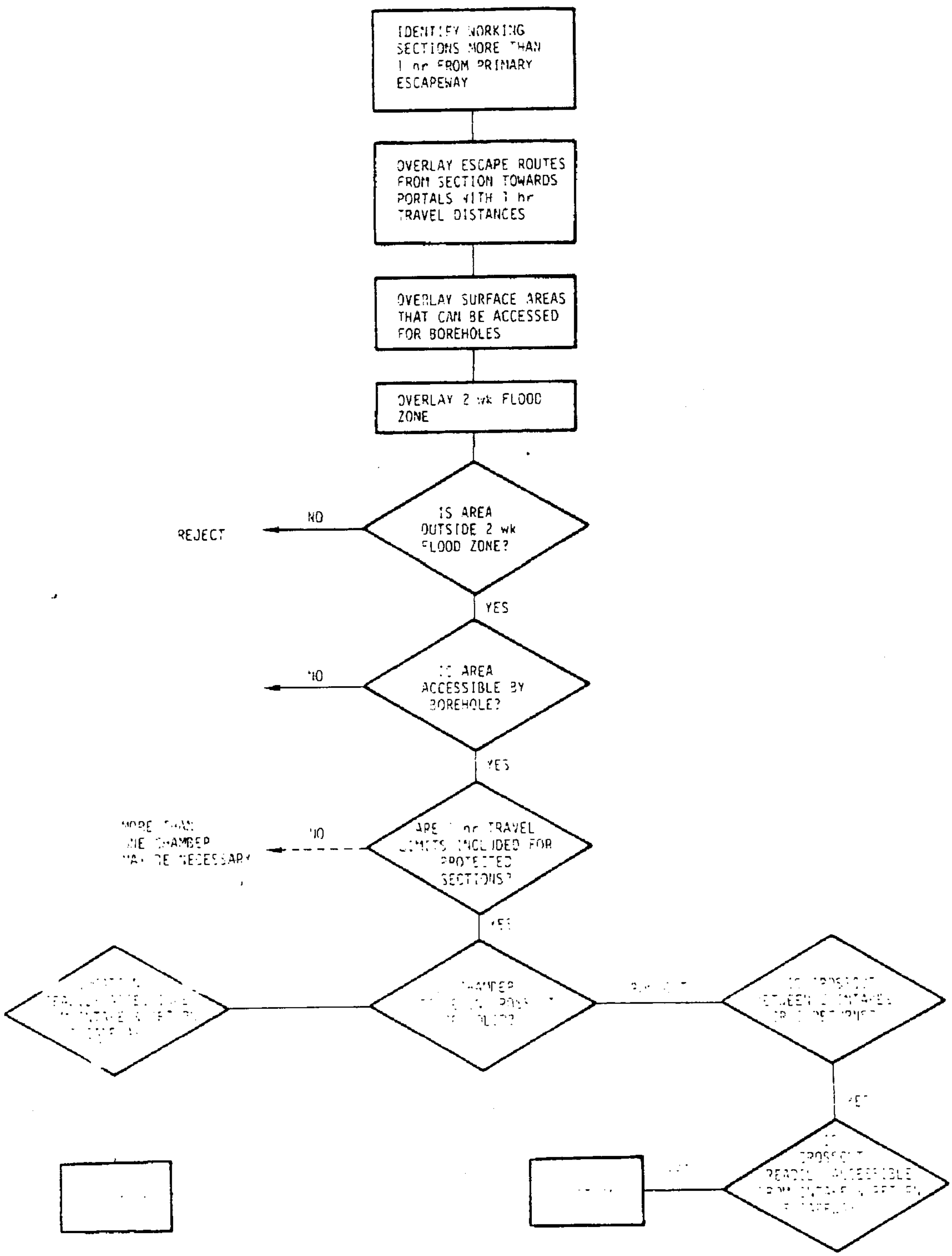


Figure 14. - Chamber location logic

5. POWER AND LIGHTING

5.1 Technical Discussion

During operation of rescue chambers, the critical power requirements are for:

a. Lights

b. Communications equipment

c. Instruments.

Communications are critical for both aid in rescue of the entrapped miners and for the psychological well being of the chamber occupants. While recovery of miners can be achieved without communications, the operation would be far more stressful on both rescuers and the entrapped, which could result in persons undertaking far greater chances than necessary.

Most required instrumentation does not require power other than possibly a manual air pump or small batteries.

In addition to the obvious practical requirements, lighting of the chamber is a psychological requirement.* Persons deprived of light will be under much higher stress than those with light available to them. This stress can decrease the efficiency of coping with the entrapment and have some persistence after a person is rescued.

Because of the importance of lighting, a nonelectrical fallback light source is recommended, such as chemilluminesence light tubes. These tubes give off a cool low temperature light due to chemical reactions. Tubes with a 12-hr light life cost about $2.10 (1983 price).

There are several general sources of power available, including:

a. Power line

b. Batteries

c. Motor/generator set

d. Human power.

*See Appendix F, especially Section F.4.4.2, page 112 (Vol.II).

Within these guidelines several of these sources are recommended. However, all electrical installations must meet MSHA requirements for permissibility. For a chamber connected to the surface by a borehole, it is required that a power line from the surface be installed in the borehole and that this line be dedicated to rescue chamber use only. It is not to supply power to any other place in the mine. With such a line, all chamber power requirements can be met.

For chambers without a borehole connection to the surface, a dedicated power line is not considered practical because all power into the mine is likely to be cut off during a disaster. For these chambers, a combination of power sources is recommended. Batteries are recommended for instruments and communications equipment. Dry cells are to be stored in sufficient quantity to operate the respective equipment for more than 14 days of operation. These stored batteries are to be replaced before half their shelf life time has passed. Additional power is to be extracted from the compressed airstream to power at least one chamber light. Commercial air motor/generator light units exist which provide light from a compressed airline in a single packaged unit. Other air motor/generator units may be used. For a rough estimate of power available assume 350W for each 30 ft^3/min from a 100 $lb/in.^2$ air supply.

Optionally, other power sources may be installed in addition to those described above. However, such equipment must not introduce additional hazards, such as:

a. Fire or explosion

b. CO or CO_2 contamination to the chamber atmosphere

c. Oxygen depletion of the chamber atmosphere

d. Overheating of the chamber.

5.2 Guidelines for Power Supply

5.2.1 General

Rescue chambers shall have sufficient lighting, and power for instruments and communications equipment.

5.2.2 Lighting

All rescue chambers shall be equipped with a store of 12-hr chemilluminesence lighting tubes sufficient to last 30 days, that is, 60 tubes.

5.2.3 Batteries

Batteries shall be available to operate any stored equipment for the design use time of the chamber with one complete set of spares. All batteries shall be renewed with fresh ones when or before one-half their shelf life is reached.

5.2.4 Testing

All power supplies shall be functionally tested on completion of the installation of the rescue chamber and on or within 30 days of the previous test. All deficiencies shall be corrected.

5.2.5 Other Power Sources

Other power sources are permitted in addition to those stated in subsections 5.2.2 and 5.2.3 (see discussion in subsection 5.1), providing they satisfy MSHA permissibility requirements or a variance is granted.

6. EQUIPMENT AND SUPPLIES

6.1 Discussion

6.1.1 General

The previous sections have discussed the design, construction and atmospheric conditioning of rescue chambers. This section provides a detailed list of equipment and supplies that must be permanently stored and maintained in the rescue chamber in order to fulfill its ultimate purpose.

The major items that must be provided in the rescue chamber are:

a. Food

b. Water

c. Miners' first aid and medical supplies

d. Self-rescuers

e. Gas detectors

f. Cots, blankets

g. Sanitary supplies

h. Body pouches

i. Sundry materials

These items are discussed in more detail in the following subsections.

6.1.2 Food

Food requirements are generally agreed to be 1740 calories/person/day. Military rations are most suitable for survival purposes and provide sufficient calories to keep a person active. A single meal of military C-ration comes in a package measuring about 15.5 cm × 12.5 cm × 8 cm (1550 cm^3). Considering three meals/person/day, the total volume of food for 15 people to last 14 days would be

$$3 \times 15 \times 14 \times 1550 \text{ cm}^3 = 34.5 \text{ ft}^3 \approx 35 \text{ ft}^3$$

For a rescue chamber 6 ft high and 18 ft wide, this would occupy about 0.32 ft or about 4 in. in depth.

The total cost of food when estimated at the rate of \$2.80* per meal** would be \$1,760.00. An analysis of a typical military ration meal reveals that at least 31.3 gr of protein, 0.36 gr calcium, 0.69 gr phosphorus and 0.005 gr iron are supplied by each meal. For three meals a day this would far exceed the recommended daily consumption of 75 gr protein, 0.69 gr calcium, 1.32 gr phosphorus and 0.0015 gr iron as suggested in Handbook of Chemistry and Physics.

The Westinghouse (2) report on Coal Mine Rescue and Survival Systems suggested the military ration (MIL-F-43231), Food Packet, Survival, General Purpose) which could also be considered for the rescue chamber requirements. This military ration also meets all the requirements and can be a viable alternative.

Other types of food, such as camping foods, could be considered for storage. However, a detailed analysis of these alternatives would be required to assure that they had adequate nourishment and shelf life.

6.1.3 Water

Sufficient quantities of drinking water must be provided to the occupants of the rescue chamber to replace their body moisture loss due to insensible perspiration and sweating. The dotted curve in Figure 15 shows the amount of moisture evaporated by *sedentary* adults for various dry bulb temperatures. Not included is moisture loss in the urine and feces or for any other reason. When these losses are included, the total moisture loss is much greater as indicated by the solid line curve in Figure 14.

Test data on water consumption during shelter occupancy tests indicate that the water consumption tends to follow the evaporative heat loss curve (11).

For a safety factor, assume a high chamber temperature such that the water requirement is about 2-1/4 quart/person/day. This is a somewhat higher requirement than the 2 quarts/person/day used in the Westinghouse study (2).

The total water requirements in the rescue chamber for 15 people to last 14 days would be $15 \times 14 \times 2\text{-}1/4 = 473$ quarts or 118 gal.

*All dollar figures in 1983 dollars; see Foreword.

**Telephone conversations with ration vendors.

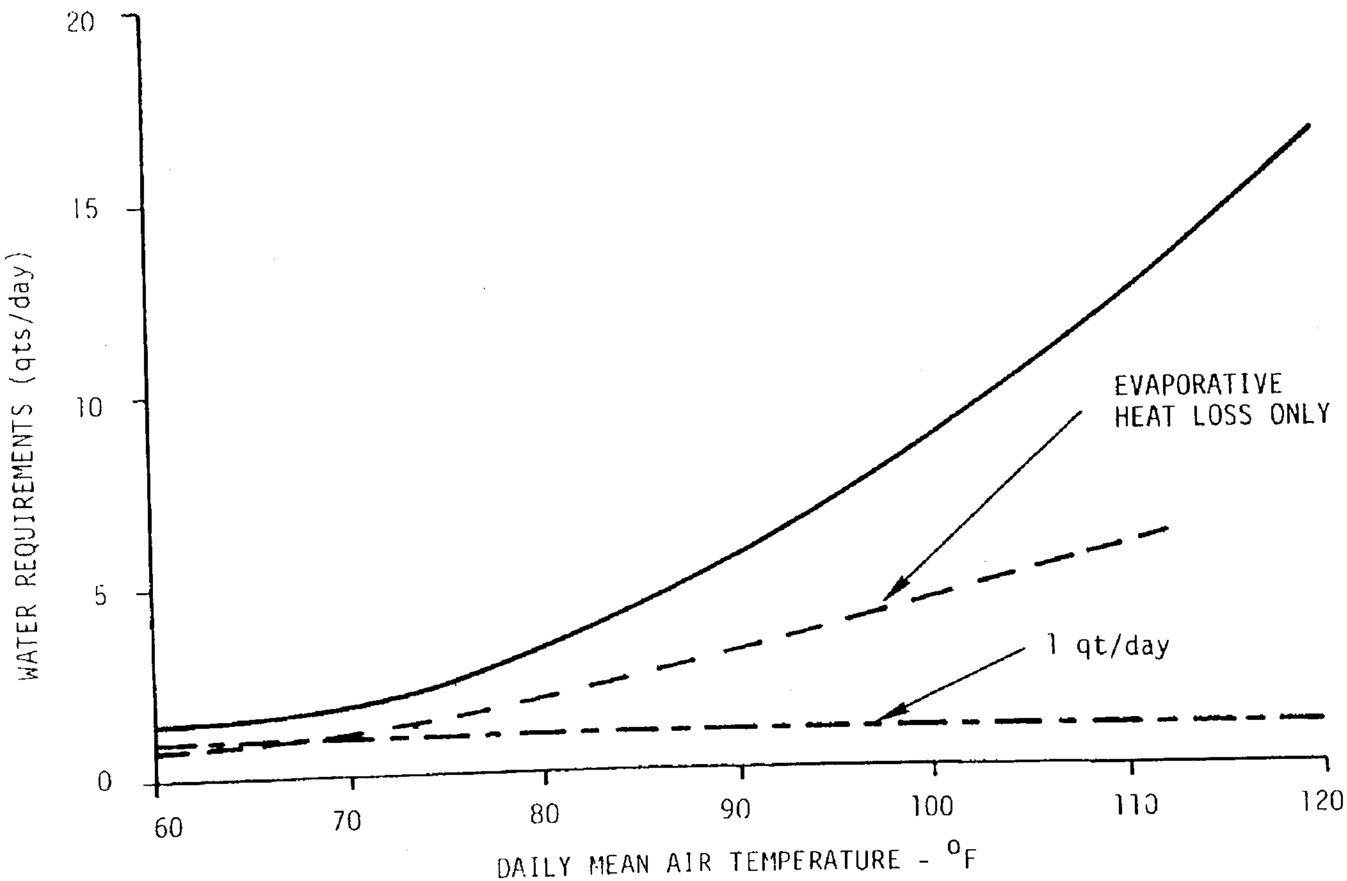


FIGURE 15. - Daily water requirements to avoid dehydration in man at rest.

The water is to be stored in 24 5-gal plastic containers costing about $5.00 each. The containers would occupy about 17 ft^3 of space in the chamber. A teaspoon of liquid bleach would be added to the water in each container to assure long storage life.

6.1.4 Miners' First Aid and Medical Supplies

First aid equipment to be supplied is the standard miners' first aid station kit. This kit contains:

1 Army stretcher

1 Rubber blanket

2 Wool blankets

3 Splints, wood, 22 × 4 × 1 1/2 in., for broken-back splinting

1 Splint, wood, 42 × 6 × 1/2 in.

2 Splints, wood, 84 × 6 × 1 in. for broken back splinting

6 Splints, 18 × 3 1/2 × 1/4 in.

2 Inflatable Jobst splints, full leg

2 Inflatable Jobst splints, full arm

24 Triangular bandages, 40 in.

8 Compress bandages, 4 in.

4 Pkg compress bandages, 16, 2 in.

1 Pkg adhesive bandages, 16, 1 × 3 in.

2 Tourniquets

1 Foille ointment, 1/2 oz

1 Ammonia, aromatic spirits, 2-oz bottle

While somewhat arbitrary, it would seem that a miners' first aid station should be installed at the rate of one station/five persons. For example, a rescue chamber designed for 15 persons should have three first aid stations available. The cost of a miners' first aid station is about $530 each. Additionally, each person should be provided with a wool blanket which can be used for general protection as well as first aid use.

6.1.5 Self-rescuers

The number of reserve self-rescuers to be stored in the rescue chamber should correspond to the number of persons taking refuge in the chamber. The new compact 1 hr self-contained oxygen self-rescuers are a significant development and could be utilized by the persons in the shelter. For a rescue chamber sheltering 15 persons at least 15 self-rescuers of the self-contained oxygen type should be stored and maintained inside storage containers.

The self-rescuers currently cost about $600 each. Total cost for self-rescuers would $9000.00.* The maximum storage volume required would be 10 ft^3.

6.1.6 Gas Detectors

The persons in the rescue chamber should monitor the quality of the air in the rescue chamber. For this purpose, gas detectors for carbon monoxide, carbon dioxide, hydrogen sulfide and methane should be provided.

The monitoring of CO, CO_2 and H_2S can be carried out using the Universal Tester Pumps. Glass detection tubes, containing chemical reagents specific to the gas being monitored, have break off tips which fill the orifice of the pumps. They indicate the presence of the gas being analyzed by a color change. The pump costs $210.00 and the tubes are packaged in boxes, each box containing 10 tubes. Each box of tubes costs about $17.00. The number of spare tubes for each type of gas is estimated as:

$$1 \text{ tube/hour} \times 14 \times 24 = 336 \text{ tubes}$$

Therefore, about 34 boxes of tubes for each gas have to be purchased. The cost would be:

$$34 \times 3 \times \$17.00 \approx \$1730.00$$

The tubes have a minimum 2-year shelf life.

The modern methane detectors use sealed rechargeable 2.4V nickel-cadmium batteries. These units can provide up to 200 readings before requiring recharging and cost about $590.00 each. Recharging takes about 14 hr. If methane is to be monitored every 5 min, at least two detectors should be provided in the rescue chamber.

*1983 dollars; see Foreword.

Nickel-cadmium batteries must be run through deep discharge cycles periodically or they lose their capacity to fully discharge. For this reason, an effort should be made to obtain methanometers which can use alkaline cells. Information on battery maintenance is given in Section 5.

6.1.7 Bunks, Sanitary Supplies and Sundry Materials

Double deck bunks constructed of 1 in. tubular aluminum can be provided in the rescue chamber for comfort. This type of bunk is easily available from major department stores and costs about $70.00*/double bunk. They can be folded when not in use and are about 39 in. high when opened.

Comparable wooden (pine) bunk beds cost about $350.00 each.

$$\text{Cost of bunks} = 70 \times 8 = \$560.00$$

A sanitary approved toilet which uses disposable bags can be provided. These toilets can be easily obtained from camping suppliers and cost less than $15.00 each.

Blankets, accounted in the emergency supply, can be used when the occupants are resting.

6.1.8 Sundry Materials

Caulking is useful for sealing purposes should there be any leaks. Aluminum wire can be used to hang clothing. Picks, hand shovels, duct tape, electrical tape, canopeners, and flashlights prove handy during emergency situations.

Table 10 gives a cost summary for supplies.

6.1.9 Body Pouches

In an emergency situation which would require the use of a rescue chamber, there is the possibility that miners will receive injuries which will result in death while the person is inside the rescue chamber. Bodies in the rescue chamber are problematic to the living in that considerable psychological stress may occur (see Section 8). A large factor producing this stress is the odor of decay as well as the sight of the body. To reduce the stress, the use of body pouches is recommended. These are plastic bags which shield the body from sight and seal in the odors of decay.

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*1983 dollars; see Foreword.

TABLE 10. - Cost summary

Food	$1760.00
Water Containers (Plastic) (24 × 5.00)	120.00
First Aid and Medical	2650.00
Oxygen Self-Rescuers (600 × 15)	9000.00
Gas Detectors	
a. CO, CO_2, H_2S	1880.00
b. Methane	1180.00
Bunks	560.00
Toilet	15.00
Sundries	100.00
	Total ≈ $17,265.00

Body pouches may be purchased from local mortuary suppliers or morticians for a cost of about $50.00 each. The number of pouches that should be stocked is difficult to estimate. A safe number is one equal to the design population of the chamber as this would allow for a possible overload case.

6.2 Guidelines for Equipment and Supplies

6.2.1 Food

Food shall be stocked in rescue chambers at the rate of 1740 calories/person/day based on the design number of people and design duration. This food shall be packaged for long-term storage, such as MIL-F-43231.

6.2.2 Water

Water shall be stocked in a rescue chamber at the rate of 2 1/4 quarts/person/day based on the design number of people and the design duration. The water is to be stored in 5 gal containers and treated against bacteria growth (see subsection 6.1.3).

6.2.3 First Aid Station

A miners' first aid station shall be stocked in a rescue station at the rate of one station per five persons (based on design). Additionally, wool blankets at the rate of one/person (based on design number) shall be stocked.

6.2.4 Gas Detectors

A gas detector tube pump and detection tubes shall be stocked in rescue chambers. The detector tubes shall be for CO, CO_2 and H_2O all for the lowest level of detection available except for CO_2 which should indicate up to 3 percent. Tubes for each gas shall be stocked at the rate of one tube for each hour (design hour).

Two methane detection instruments shall be stocked in each chamber.

6.2.5 Cots

A sleeping cot shall be stored at a minimum of one for each person (based on design number).

6.2.6 Toilet

At least two sanitary toilets shall be installed in each chamber. These toilets may be of the seat and plastic bag type as used in camping. Sufficient bags must be supplied.

6.2.7 Body Pouches

Body pouches (see subsection 6.1.7) shall be installed at the rate of one/person based on design.

6.2.8 Other Materials

Other materials shall be stored in the rescue chamber as discussed in subsection 6.1.7.

6.2.9 Inspection and Maintenance

All stored materials shall be noted on an inventory list. The material stored shall be inspected periodically in intervals not to exceed 6 months and any materials missing from the inventory list or noted deficient shall be replaced.

7. RESCUE CHAMBER COMMUNICATIONS

7.1 Discussion

7.1.1 General

Rescue chambers can save lives without communications to the surface; however, two-way communications between the entrapped miners in the chamber and the rescuers offers considerable aid and efficiency in the process of removing the entrapped as well as offering psychological comfort to chamber occupants. In order to ensure chamber-to-surface communications, these guidelines specify the installation and maintenance of redundant communication links. The particular systems installed depend on the type of rescue chamber and the present (1979) state-of-the-art of mine communications in the United States. Reference is made to some emerging communication systems, and provisions are made within the guidelines for the application of this technology once it has become commercially available.

The prime communication system covered by these guidelines shall be telephones. Both the mine pager phones, and the less commonly used (underground) some powered phones are specified. Installed redundant lines are required as protection against the loss of communication due to cable breakage. A seismic system is specified as a fallback in case all phone lines are severed. Not specified, but permitted by these guidelines, is the use of electromagnetic wireless links which may be installed in addition to the phone and seismic links.

The remainder of this section discusses the telephone instruments, the wiring requirements, the seismic systems and two emerging wireless technologies. Subsection 7.2 presents the specific requirements for rescue chamber communications.

7.1.2 Telephones

The code of Federal Regulations, Title 30, Mineral Resources, requires communications in underground coal mines. As a result, all coal mines presently have an installed telephone system, usually a mine pager phone system. Rescue chambers should take advantage of these already installed systems.

Reference 12 is suggested as a reference for the technicalities of pager phone systems and the techniques of underground wiring.

Sound powered phones have advantages for use in rescue chambers. The instruments are sturdy enough for military use and no electrical power is required even up to ranges of 30 mi over No. 19 AWG cable.*

Transmission by sound powered phones works as a speaker in reverse. Air pressure variation (sound waves) from a voice moves a diaphram which moves a magnetic field across a coil. This generates an electrical signal that is conducted over a cable to a receiver where the electrical signals drives a speaker in a telephone handset. The only source of power is the voice.

Various types of sound powered telephones are available. For rescue chambers, a pair of simple handsets located at the surface and within the rescue chamber is sufficient. Such instruments cost about $120 each (1983 price). These simple instruments do not have a signaling (ringing) system, however, but blowing a police whistle can provide a suitable signal at the other phone if a telephone watch is maintained.

The next subsection discusses methods for connecting rescue chamber telephones with surface communication stations.

7.1.3 Connecting Lines

Redundancy in connecting telephone lines between rescue chambers and a surface communication station(s) will be used to ensure against loss of communication. Two methods are required by these guidelines: a loopback of the pager phone line and a dedicated line for a sound-powered phone.

Both of those connecting methods are shown schematically in Figure 16. The loopback line is good general practice, as it protects the mine pager phones against loss of communications due to a line break, even during normal mine activities. In a mine emergency which requires the use of a rescue chamber, the loopback line provides two independent pager phone lines to the surface, with a likelihood of at least one line surviving the cause of the emergency. A necessary feature of this system is the transfer switches shown next to both surface and chamber pager phones. These switches must be of an environmentally sealed, double-pole, double-throw type. If one of the lines connecting the surface phone to the rescue phone is short-circuited, these switches can be used to transfer the phones to the good line.

The sound-powered phones must be connected to a separate dedicated cable, which is routed along a path independent of the loopback pager phone lines. All telephone lines must have lightning protection installed. Furthermore, care should be taken not

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* Stromberg - Carlson Brochure

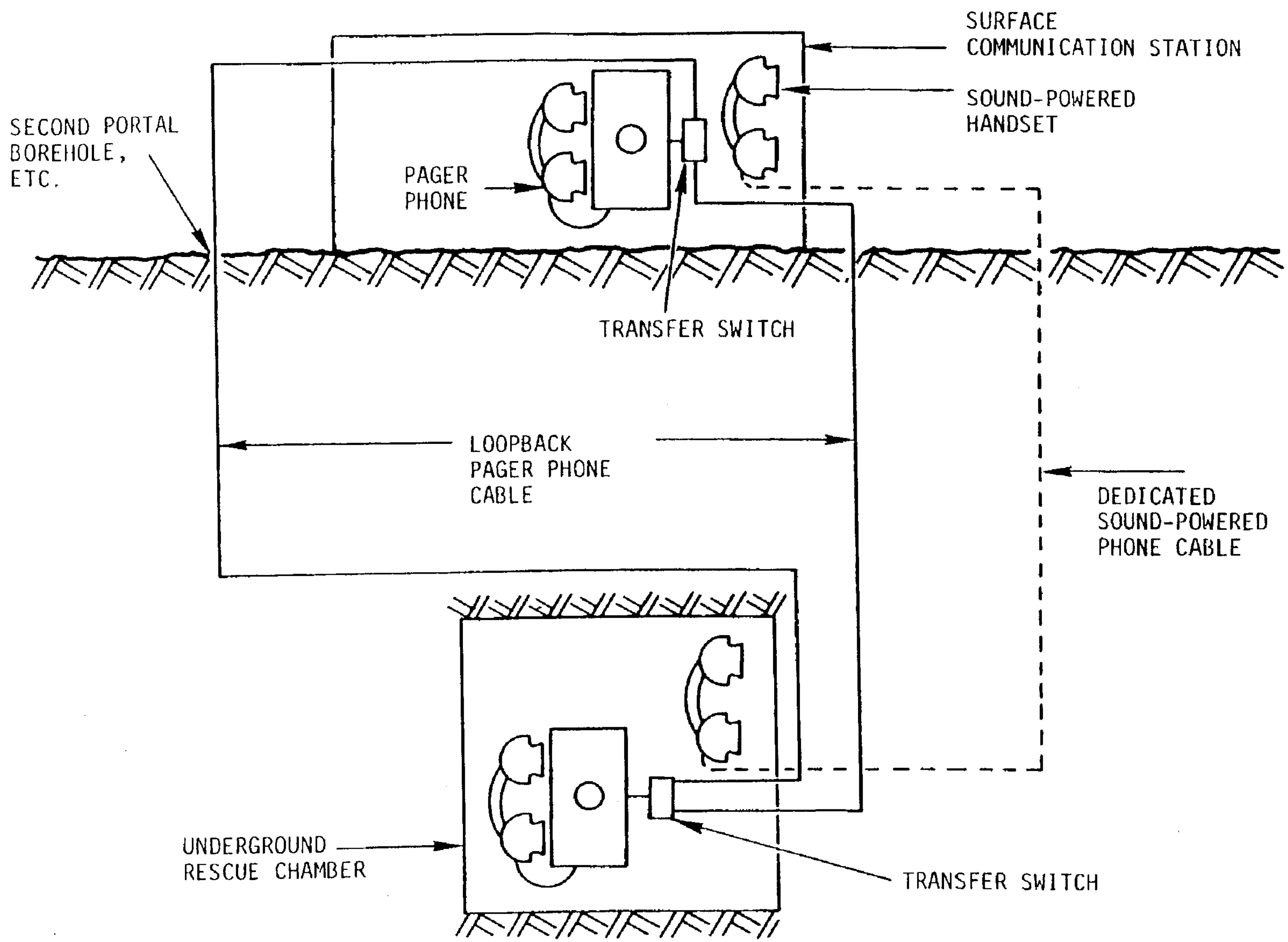

Figure 16.- Schematic of connecting telephone lines.

to install phone lines in proximity to power cables so that in an accident situation, it will be impossible for high voltage to be connected to the phone lines.

The typical cost of installing mine phone cable may be estimated on the basis of a wireman and helper installing 2000 ft of cable during a shift at a combined cost of $365.* Taking the cost of cable and miscellaneous hardware as $350/1000 ft, the installed cost of 1000 ft of cable may be estimated as:

$$\frac{\$365\ \text{(labor)}}{2000\ \text{ft}} + \frac{\$350\ \text{(materials)}}{1000\ \text{ft}} = \frac{\$350}{1000\ \text{ft}}$$

If circumstances should conspire such that there is a loss of both pager phone and sound-powered phone, then a fallback primitive seismic signaling device could be resorted to. This is described in the following subsection.

7.1.4 Seismic Signaling

Seismic signaling is probably the oldest form of mine signaling. It is based on the detection of through-the-earth vibrations produced by miners impacting the mine roof or ribs with a heavy object. The modern version of seismic signaling uses geophones on the surface to detect the vibrations underground, and surface detonation of explosives to signal back to the underground miners who hear or feel the vibration due to the explosions.

Simple procedures and codes have been established for this type of signaling. MSHA has Mine Rescue and Survival Teams that travel to disaster sites and operate the surface seismic signaling equipment. Information from MSHA on signaling codes and procedures should be obtained and copies placed within the chamber for use, if necessary, by entrapped miners. Additionally, impacting tools, such as timber, should be placed in the rescue chamber. Recommended are a 40 lb timber (about 4 ft long) for two person use, and a 10 lb timber for single person use.

7.1.5 New Technology for Communications

There exists emerging technology in electromagnetic, through-the-earth, wireless communications. These systems are not commonly available for use in the United States at this time (1979); however, they are well advanced and could become readily available under favorable circumstances.

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*1983 dollars.

Two systems will be mentioned herein which are most likely to have impact in the near future. A USBM trapped miner system which operated at voice or ultra-low frequency has been developed and tested through prototype stage. At present, this is a portable system carried by the miner and powered from his cap lamp battery. If the equipment becomes commercially available, systems could be installed within the rescue chamber.

The other system is a medium frequency radio developed, sold and used in South Africa. Presently this system has not met United States permissibility requirements. However, the potential exists that this equipment could become available for use in the United States in the near future, and hence could be installed in a rescue chamber.

These guidelines permit, but do not require the installation of a new communications system, in addition to the required telephone and seismic systems.

7.2 Guidelines for Communications

7.2.1 General

Rescue chambers shall have the following installed communications equipment. This equipment shall include:

a. A mine pager phone on a loopback line with transfer switches at the phone underground and on the phone on the surface as described in subsection 7.1.3

b. A sound-powered phone pair located in the rescue chamber and at a surface location connected by a dedicated line as described in subsection 7.1.3

c. Equipment and directions for seismic through-the-earth signaling as described in subsection 7.1.4.

The telephone equipment shall be installed and maintained by the methods described in "Technical Guidelines for Installing, Maintaining and Inspecting Underground Telephone Systems," a USBM Handbook, U.S. Departmentof the Interior (1978 or subsequent versions).

7.2.2 Borehole Connected Rescue Chamber

A borehole connected rescue chamber shall have the sound powered phone line installed up through the borehole to the surface.

7.2.3 Airline Supplied and Stored Compressed Air Rescue Chambers

Airline supplied and stored compressed air rescue chambers shall have all telephone lines run via independent routing while underground. At each point where a cable from a rescue chamber reaches the surface, it shall be clearly marked stating that the cable is a telephone cable to a rescue chamber with the location of the chamber indicated.

The mine emergency map shall clearly show the routing of sound-powered phone lines to aid underground rescue teams in finding a point to tap into for direct communications to the chamber.

7.2.4 Operation and Training

All mine personnel likely to use the rescue chamber shall be instructed in the use of communications systems, including the use of the transfer switch on the pager phone, the use of the sound-powered phone, and the use of the seismic signalling device.

Directions for use of communications equipment shall be posted in the rescue chamber.

Mine personnel shall also be instructed in identifying and preventing the cutting of the phone cables to rescue chambers before or during a rescue attempt.

7.2.5 Testing and Maintenance

All communications equipment in a rescue chamber shall be tested for proper operation on installation and every 6 months thereafter. Any deficiencies shall be immediately corrected.

8. PSYCHOLOGICAL ASPECTS AND TRAINING

8.1 Discussion

Discussion of the use of rescue chambers has frequently raised the question of what will be the psychological effects on the miners, such as: their ability to cope with the situation well enough to look out for their physical well-being; and the possibility of long-term psychological impairment to miners who have experienced entrapment. As part of the development of these guidelines, the psychological aspects of the use and training for use of these guidelines were examined.

This examination is presented in detail in Appendix F. Although the data based is limited, conclusions indicate that miners will be able to cope successfully with using rescue chambers, and that long-term after-effects are not expected.

Examination of cases where miners have been trapped for long periods has indicated two particular requirements. One is that chamber lighting is required, the other is provision must be made for removing dead bodies from sight and more importantly shielding the living from the odor of decaying bodies. Both of these items have been provided for elsewhere in these guidelines (lighting under power, body containment under supplies).

8.2 General

The expected psychological problems associated with prolonged confinement to rescue chambers are: anxiety, withdrawal, apathy, aggression, hostility, depression and irrational, impulsive behavior.* Miners are expected to suffer more from the immediate shock of the disaster itself, and the resultant presence of dead and injured persons, than any other variables. Initial shock and panic will be the immediate symptoms of the disaster. Disbelief, confusion and disorientation will probably be present for the first few hours. Some phobic reactions to the possible recurrence of the disaster can also be expected. The way in which miners are able to cope with this *initial* shock should determine how successfully miners tolerate their confinement. After the immediate shock effects have worn off, which should not last more than a few hours, the miners will suffer some anxiety, in the form of survival guilt. The miners are expected to feel discomfort from the confinement itself, but such discomfort is expected to be superceded by the more potent effects associated with death. There will be increasing anxiety as the number of days of confinement increases, especially if the miners

*The general conclusions in this section are based upon the discussion and documentation in Appendix F, Volume II and the 77 references cited therein.

are in a chamber that has a limited supply of stored compressed air. But this anxiety, which in extreme cases such as limited air supply and/or loss of communications can be expected to reach intolerable limits by the 13th or 14th day, will be due more to the fear that they will not be rescued than to anything else. It is not expected that any temporary or permanent psychological incapacitation will occur. The effects of group standards upon individual behavior are expected to discourage this.

8.3 Guidelines for Psychological Aspects

A training program which accomplishes the following is recommended:

a. Teaches the miners how to respond effectively to the immediate disastrous condition, which will likely be a mine explosion. Responses which must be learned in this section of the program are:

   1. How to detect the nature of the disaster. Is it a mine explosion? Is it a major roof fall? Where is it located?

   2. How to protect oneself from the immediate effects

   3. How to decide whether to attempt to escape or to seek refuge - a function of the particular mine

   4. What symptoms to observe in others and in oneself that are a result of the trauma, and how such symptoms can be controlled.

b. Teaches the miners how to care for the injured, and how to operate emergency equipment, such as:

   1. The 1 hr breathing devices

   2. The carbon dioxide removal agents

   3. Getting communication to the outside.

c. Teaches miners how to deal with the dead, injured, and emotionally unstable. A decision to attempt rescue of others might have to be made at this point.

d. Teaches miners how to handle the stresses of confinement. The following factors should be considered:

1. The importance of roles and role relationships, as they are expected to apply to the unique conditions of the mine. These roles will be partly controlled by the personality, interpersonal, group dynamics, and psychological forces which occur in the rescue chamber environment. They seem to be determined by two types of conditions: the impact period, which is characterized by task-oriented behavior; and the survival period, which is characterized by emotionally-oriented behavior.

2. The expected types of behavior during confinement.

e. Teaches the miners specific tasks to perform. The essential tasks are:

1. Manager selection (by experience)
2. Supply inventory
3. Emergency equipment review
4. Reconnaissance
5. Manager selection (by vote)
6. Food, water rationing
7. Medical services
8. Atmosphere control
9. Sanitation services
10. Recreational services
11. Sleeping arrangements (may change)
12. Security of rescue chamber.

9. REFERENCES

1. National Academy of Engineering, Committee on Mine Rescue and Survival Techniques, *Mine Rescue and Survival*, USBM Open File Report 4-70, Washington, DC, March 1970.

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11. Department of Defense, Office of Civil Defense, *Shelter Design and Analysis*, Vol. 3, Environmental Engineering for Shelters, TR-20-Vol. 3, May 1969.

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Comments from Spreadsheet

<u>ChemBio/AL Lee Comments</u>

C1 Tent began collapsing at 7 hrs due to cut in main air tube. No instructions on how to reinflate. Curtains were knocked over, absorbed water and reduced their scrubbing efficiency.

C2 CO_2 concentration at 96 hours was 1.20%.

C3 Tent collapsing began again at 80 hrs and was nearly completely collapsed by 96 hrs.

C4 O_2 flow rate between 10 and 18.5 l/min. For 20 man chamber, flow rate should have been app. 12.4 l/min.

<u>Strata Products Comments</u>

S1 CO_2 above 0.5% for first 16 hrs because CO_2 flow rate into chamber was 28% greater than needed for 36 man chamber (App. 23.4 l/min vs. 18.3 l/min). Once correct CO_2 flow rate attained, CO_2 conc. remained below 0.5%.

S2 Scrubber fan motor seized and was changed out 73.5 hrs. into test (extra motor and complete instructions were included).

<u>Kennedy Comments</u>

K1 CO_2 ranged from 0.24 to 0.72%. Pattern was the CO_2 level went above 0.5% just prior to curtain change. After new curtains were hung, CO_2 level dropped below 0.5%, then slowly climbed above 0.5% until next curtain change.

K2 For the first 3 curtain change outs (12, 24 and 36 hrs) the CO_2 level dropped below 0.5% for between 7 and 9 hours afterward then went above 0.5%.

K3 For remaining curtain change outs (48, 60, 72 and 84) CO_2 was below 0.5% for 4 hrs or less before climbing above 0.5%.

K4 The valve on one O_2 bottle was never opened, thus more than enough O_2 was available for 12 man capacity.

<u>Modern Mine Safety Comments</u>

M1 Maximum CO_2 recorded reading occurred during first soda lime change out (1.94% was observed but not recorded).

M2 CO_2 levels went above 0.5% after initial 4 hours of evaluation, reaching 0.61 just prior to first change out.

M3 After first change out CO_2 levels dropped to 0.25 within 30 minutes.

M4 CO_2 levels remained below 0.5% for nearly 32 hours without a second change out of scrubbing material.

M5 O_2 flow rate fluctuated between 10.5 and 12.5 l/min, only 4 of 11 O_2 cylinders were empty.

M6 Battery powered blower ran the full 96 hrs.

AB58-COMM-33-11

Survivability Evaluation of Mine Refuge Chambers

Report Date: Dec. 19, 2007

		Evaluation 1	Evaluation 2	Evaluation 3	Evaluation 4
	Chamber Name	Life Shelter	Fresh Air Bay	Kennedy Chamber	Mine Refuge Chamber
	Model Number	4042-20	MC36	MPRC-H12-8155-C	MMS - 26
	Manufacturer	ChemBio/AL Lee	Strata Products	Kennedy Metal Products	Modern Mine Safety Supply
	Street Address	968 Postal Road, Suite 320	3939 Roswell Road, NE Suite 100	P.O. Box 138	P.O. Box 480
	City	Allentown	Marietta	Taylorville	Huntington
	State	PA	GA	IL	UT
	Zip Code	18109	30062	62568	84528
	Telephone	610-266-6667	770-321-2501	217-287-7231	435-687-2244
Specs	**Chamber Type**	Inflatable	Inflatable	Steel	Steel
	Capacity (persons)	20	36	12	26
	CO2 Scrubbing System	Passive soda lime curtains	Powered soda lime cartridges	Passive lithium curtains	Powered soda lime
	Basis to Change Scrubbing Materials	Specified time - 96 hrs	Specified time - 24 hrs	Specified time - Variable	Specified time - 16 hrs
Evaluation	**Arrival Date**	10/29/07	11/02/07	10/26/07	11/30/07
	Set-up Date	10/29/07	11/05/07	11/09/07	12/03/07
	Evaluation Start Date	10/30/07	11/05/07	11/13/07	12/03/07
	Evaluation End Date	11/03/07	11/09/07	11/17/07	12/05/07
	Clean-up Date	11/03/07	11/09/07	11/17/07	12/06/07
Results	**CO_2 Scrubbing Criteria (0.51 l/min/man)** *(CO_2 level <= 0.5%)*	Exceeded	Met	Exceeded	Exceeded
	Comments	Exceeded 0.5% 42 hrs into test, remained above 0.5% from 44 hrs to end (See Comments C1, C2, C3)	Stabilized at between 0.35% and 0.40% (See Comments S1, S2)	Maximum reading was 0.72% (See Comments K1, K2, K3).	Maximum recorded reading was 1.34% (See Comments M1, M2, M3, M4)
	O_2 Supply Criteria (0.62 l/min/man) *(O_2 >= 19.5%)*	Insufficient	Met	Met	Insufficient
	Comments	O2 flow to zero at app. 71 hrs (See Comment C4)		O2 flow and conc. starting dropping at 94.5 hrs (See Comment K4).	O2 flow ended after 37 hrs (See Comment M5)
	Apparent Temperature Criteria *(< 95 deg F)*	Met	Met	Exceeded	Exceeded
	Comments	Stabilized at app. 70°F apparent temperature (73°F and 62% RH)	Stabilized at app. 70°F apparent temperature (70°F and 69% RH)	Apparent temperature app. 110°F (87°F and 86% RH).	Apparent temperature max. of 124°F (90.5°F and 92.6% RH)
	Duration Criteria *(96 hours)*	Less Than Required	Met	Met	Less Than Required
	Comments	O2 flow ran out prior to 96 hrs.			O2 quit, Failed scrubber containers and loose soda lime forced early termination.
	Early Termination Time (hours)	NA	NA	NA	56 (See Comment M6)
	Reason for Early Termination				CO2 levels to 2.0%, No O2

BBE BLUHM BURTON ENGINEERING (PTY) LTD

MINE VENTILATION AND REFRIGERATION SPECIALISTS

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REVIEW OF BEST PRACTICES REGARDING THE USE OF REFUGE CHAMBERS IN SOUTH AFRICA

SEPTEMBER 2007
BBE Report No: 5207

F.J. van Zyl
Senior Engineer
Bluhm Burton Engineering

W. Marx
Director
Bluhm Burton Engineering

AB58-COMM-33-12

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CoP	Code of Practice
DME	Department of Minerals and Energy
HIRA	Hazard Identification and Risk Assessment
OEM	Original Equipment Manufacturer
OHS	Occupational Health and Safety
ILO	International Labour Organization
MHSA	Mine Health and Safety Act
MHSI	Mine Health and Safety Inspectorate
MOHAC	Mine Occupational Heath Advisory Committee
MQA	Mine Qualifications Authority
MRAC	Mine Research Advisory Committee
NIOSH	National Institute for Occupational Safety and Health
ppm	parts per million
RH	Relative Humidity
SABS	South African Bureau of Standards
SAQA	South African Qualifications Authority
SETA	Sector Education and Training Authority
SGB	Standards Generating Body
SIMRAC	Safety in Mines Advisory Committee

1 BACKGROUND TO STUDY

BBE has been approached by the National Institute for Safety and Health [NIOSH] in the United States of America to conduct a review on the best practises regarding the use of refuge chambers in South African coal mines.

The purpose of this research effort by NIOSH is to continue to understand the issues associated with the use of refuge chambers and/or safe havens in underground coal mining operations as part of the mine escape and rescue strategies. This will assist in the development of effective mine disaster plans. Part of this understanding is to gain knowledge of refuge chamber use in other countries. This research effort will provide specific information on the characteristics of the design and use of refuge chambers and safe havens currently being used in underground coal mines in South Africa. This will include a review of regulations, risk assessment, emergency preparedness and response, performance testing of refuge chambers, and identification of chamber manufacturers.

2 BACKGROUND

The use of rescue chambers is widely practised in South African underground coal mines with both fixed and portable types of rescue chambers currently being used. The successful implementation of underground rescue chambers is dependant on various issues. Some of these are:

- The location or deployment of rescue chambers relative to the underground workforce. Factors that needs to be considered is how to safely get miners from their various places of work into and out of the rescue chambers during emergencies assuming an irrespirable atmosphere.
- The construction and maintenance requirements of rescue chambers to remain operational during underground emergencies such as the aftermath of underground methane and coal dust explosions and fires. Also of importance is the ingress and egress from the rescue chamber in situations of irrespirable outside atmospheres. Equally important is how these requirements are assessed.
- The minimum equipment and amenities required to sustain the life and morale of the miners located in the rescue chamber, e.g. air supply, water, food, communications, toilet facilities, physical environment, safety equipment, first aid, etc.
- Emergency preparedness training and frequency of exercises required to ensure that miners will be able to locate refuge chambers with provided systems in an irrespirable and zero visibility environment and to communicate effectively with rescue coordinators and personnel once secured in a rescue chamber.
- And lastly, what is the rescue strategy and stay period required to bring the miners to safety.

3 SCOPE OF WORK

The scope of work for this review is the use of rescue chambers in underground South African coal mines, with specific reference to the issues raised above as follows:

- Review the regulatory guidelines regarding the use and minimum requirements of rescue chambers;
- Evaluation of the implementation of the regulatory guidelines at major and minor underground coal mining operators, with specific reference to the Hazard Identification and Risk Assessment developed Codes of Practises [CoPs] for Emergency Preparedness and Response;
- Assessment of practical implementation of Emergency Preparedness and Response CoP, with specific focus on rescue chambers at major and minor mining operators [planning, procurement, implementation, and maintenance];
- Review of standards and best practises related to performance testing of all types of rescue chambers; and
- Identification of Original Equipment Manufactures [OEMs] of rescue chambers and associated equipment [Including overview of specific designs].

4 REGULATORY REVIEW

4.1 Regulatory Environment

The requirement for the use of underground refuge chambers in South African colliers is governed by law, namely the Mine Health and Safety Act of 1996 (Act No. 29 of 1996) [MHSA].

4.2 Origins of the Mine Health and Safety Act

The MHSA came into effect on 15 January 1997. It replaced the Minerals Act, 50 of 1991 as the legal basis for the regulation of occupational health and safety for the South African Mining Industry. The MHSA flows from an extensive policy review which originated from the Commission of Inquiry into Health and Safety in Mines ["the Leon Commission"] which held hearings in 1994 and published a report and recommendations in April 1995.

One of the four major issues identified by the Leon Commission, which required immediate investigation, was that of disasters from explosions of gas and coal dust in coal mines. This report recommended that legislation pertaining to emergency preparedness and response be developed as a matter of urgency.

From the findings of the Leon Commission the MHSA was developed following extensive tripartite consultations involving representatives from the Department of Minerals and Energy [DME], employers and trade unions in the mining industry. The Parliamentary Portfolio Committee on Minerals and Energy conducted extensive hearings on this subject which resulted in legislation which enjoys a high level of acceptance among employers and employees.

The MHSA replaced the prescriptive based Minerals Act with one that compares favorably with international standards and contemporary legislative trends. It draws extensively on the International Labor Organization [ILO] Mine Safety and Health convention 177 of 1995, which recommends a risk based approach. Certain prescriptive regulations from under the previous Minerals Act were kept in place under Schedule 4 of the MHSA [See Appendix A]. These regulations are being revised and this report will make reference to the relevant current legislation as well as new legislation being developed.

4.3 Framework for Acts in South Africa

All acts in South Africa, including the MHSA, are governed by the Constitution Act 108 of 1996. The Constitution under section 24 states that "Everyone has the right to an environment that is not harmful to their health or well being and to have the environment protected through reasonable legislative measures" [Refer to Figure 4.1].

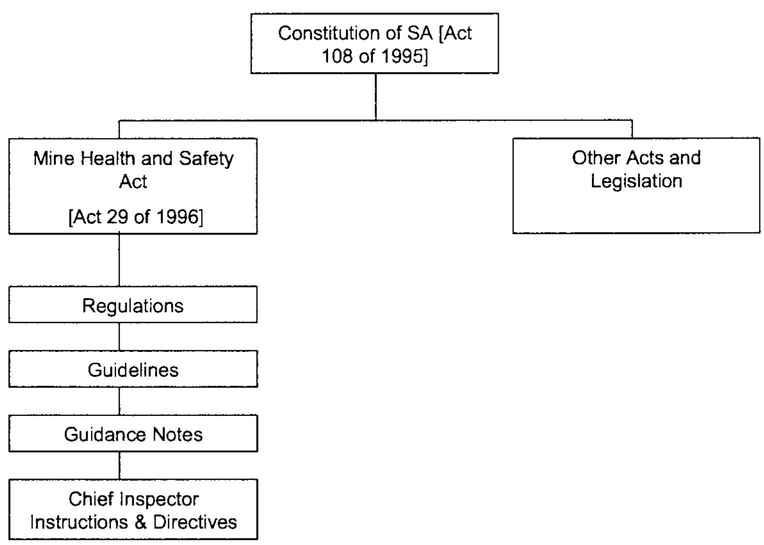

Figure 4.1 Frameworks for Acts in South Africa

The MHSA falls under the jurisdiction of the Minister of Minerals and Energy. The Minster heads up the DME which has a mandate to provide effectual governance of the minerals and energy industries in South Africa to ensure economic growth and development. One the objectives of the DME are to ensure that these industries are safe and maintain healthy working environments. The Mine Health and Safety Inspectorate [MHSI], as a department within the DME, executes this function on behalf of the DME [Refer to Figure 4.2]. The MHSI is headed by the Chief Inspector of Mines.

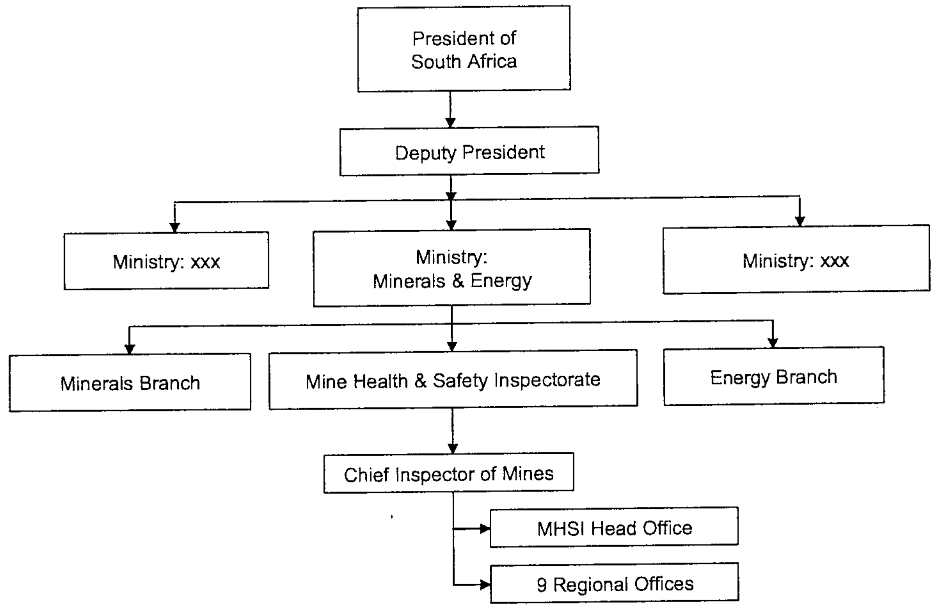

Figure 4.2 Implementation of Acts in South Africa

One of the primary functions of the MHSI is to enforce compliance with the MHSA. Other functions include inspection of mines, investigations and conducting of inquires into accidents and other health and safety incidents. The MHSIs enforcement powers include the issuing of compliance or closure notices, the imposition of administrative penalties and the recommendation for prosecutions.

4.4 Framework to Amend [Improve] the MHSA

To amend the MHSA the Minister of Minerals and Energy and the Mine Health and Safety Council [MHSC] needs to agree on proposed amendments. The MHSC functions in terms of the MHSA is to advise the Minister on Occupational Health and Safety legislation and research outcomes focused on ameliorating and promoting occupational health and safety at South African mines. The Council as well as its three statutory tripartite permanent committees consists of 15 non-executive members representing the State, Employers and Employees under chairmanship of a state member. The Permanent Committees were established in terms of Section 41[2] [Appendix B] of the MHSA and comprises the following:

- The Mining Regulation Advisory Committee [MRAC] is responsible for advising the Council on proposed changes to legislation, guidelines for codes of practice and for standards approved by the South African Bureau of Standards [SABS];
- The Mining Occupational Health Advisory Committee [MOHAC] is responsible for advising the Council on health policies, regulations, research, the management of health risks and data management; and
- The Safety in Mines Research Advisory Committee [SIMRAC] reviews occupational health and safety risks and solicits research projects, manages the conclusion of those projects and advises on the technology transfer of its results.

The organogram depicting the interaction between the various committees, the Council and the Minster is shown on Figure 4.3.

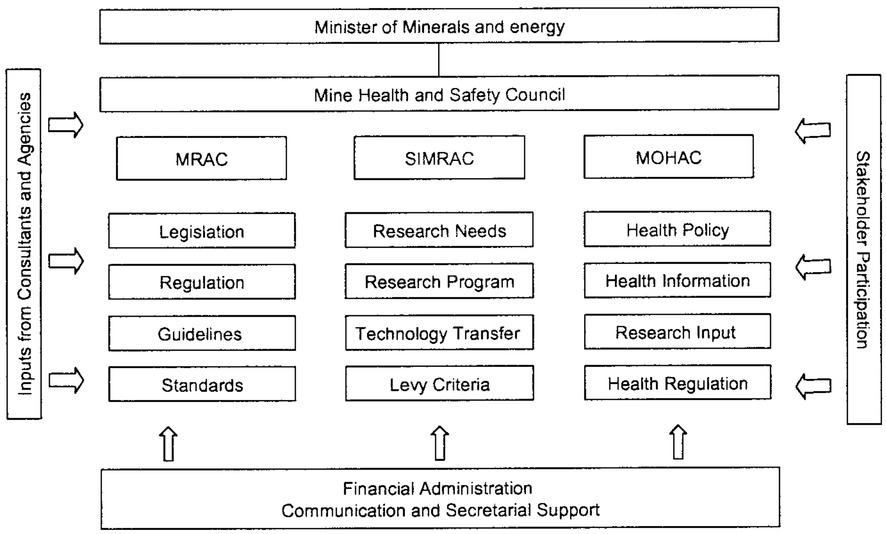

Figure 4.3 Organogram depicting interaction between committees, MHSC and the Minister

4.5 Regulatory Mechanisms

To empower the Minister of Minerals and Energy to fulfill one of the objectives of the DME [safe and healthy working environments in mines], the MHSA allows the minister to develop a regulatory framework. The principal elements of the regulatory framework are:

- Regulations;
- Guidelines for Mandatory Codes of Practice [CoPs];
- Chief Inspectors Instructions or Directives; and
- Guidance Notes.

Often the proper regulation of a topic would require making use of more than one of these regulatory mechanisms. The principle regulatory mechanisms are discussed in the following sections.

4.5.1 Regulations

Regulations are drafted where an issue is common to all mines and can be complied with. Regulations must be drafted in such a nature that mines would not need to apply for exemption from these regulations. Furthermore, regulations are to be outcomes based and hence should not prescribe to the employer on how to address a significant risk, identified in terms of the hazard identification and risk assessment [HIRA] process, but should allow the employer to implement a hierarchy of control measures to reduce or eliminate the risk.

4.5.2 Guidelines for Mandatory Codes of Practice

Guidelines are drafted where site specific flexibility is required as a result of varying conditions existing at the different mines.

4.5.3 Chief Inspectors Instructions and Directives

Directives or instructions are issued by the Chief Inspector of Mines on any health and safety matter that requires attention or to distribute information relating to health and safety at mines.

4.5.4 Guidance Notes

A guidance note sets out good practice.

4.6 Responsibilities for Ensuring Compliance with Legislation

4.6.1 Role of the Inspectorate

The MHSIs head office is responsible for the development of policy and legislation and it produces guidelines for Codes of Practice, and other guidance documents for the mining industry.

The primary functions of the Regional MHSI are to inspect mines, to investigate and conduct inquiries into accidents and other health and safety incidents and to enforce compliance with the MHSA.

4.6.2 Role of Employers

In terms of this legislation the employer is ultimately responsible for the health and safety of employees and this is inclusive of:

- A safe place of work;
- A safe system of work;
- A competent and properly trained staff and supervisors; and
- Fit for purpose plant and equipment.

The employer is required to adopt a systematic approach to identify hazards, assess the health and safety risks to which employees may be exposed while they are at work, and record the significant hazards identified and risk assessed. The employer must determine how the significant risks identified in the risk assessment process must be dealt with, having regard to the requirement of section 11[2] and [3] of the MHSA in that, as far as reasonably practicable, attempts should first be made to eliminate the risk, thereafter to control the risk at source, thereafter to minimize the risk and thereafter, insofar as the risk remains, to provide personal protective equipment and to institute a programme to monitor the risk.

4.6.3 Role of Employees

As far as employees are concerned, Section 22 of the MHSA places a number of obligations on employees, including that they must take reasonable care to protect their own health and safety and the health and safety of other persons who may be affected by their conduct. Employees also have the right to leave a dangerous working place whenever circumstances arise at that working place which, with reasonable justification, appear to that employee to pose a serious danger to the health and safety of that employee.

4.7 Current Applicable Legislation to Refuge Chambers

All refuge chamber CoPs are drawn up in accordance with Section 9[1] of the MHSA which states that "any employer may prepare and implement a code of practice on any matter affecting the health or safety of employees and other persons who may be directly affected by activities at the mine" [Refer to Appendix C].

Further to this, as stated in Section 4.6 above and referring to Section 4.2, there are currently regulations under the Minerals Act, MHSA and Chief Inspector Directives applicable to the use of refuge chambers in underground mines, including coal mines. Tables 4.1 to Table 4.3 refer to applicable legislation regarding refuge chambers in the South African mining industry.

4.7.1 Regulations

Table 4.1 Minerals Act Regulations

Regulation No	Description Of Current Regulation
24.20.2.1	The manager shall see to it that there is a refuge chamber or other safe place in a mine or works is within easy reach of workmen and within the limits of protection afforded by a self rescuing device, in the event of an explosion, fire or other emergency.
24.20.2.2 (a), (b) and (c)	Definitions and requirements of refuge chamber and other safe place and definition of respirable air. Refer to Appendix D.
24.20.2.3	A refuge chamber and other safe place shall be examined at intervals determined by the manager in consultation with the Inspector of mines, by persons appointed in writing by the manager for this purpose.

Table 4.2 Mine Health and Safety Act Regulations

Regulation No	Description Of Current Regulation
16.1(1)	The employer must ensure that a competent person reports to the employer, at appropriate intervals determined in accordance with the mine's risk assessment, on the adequacy of escape and rescue procedures at the mine relating to explosions, fires and flooding.*

Note: * The competent person referred to in regulations 16.1[1] must be in possession of the Certificate in Mine Environmental Control, issued by the Chamber of Mines of South Africa.

4.7.2 Guidelines for Mandatory Codes of Practice

A new "Guideline for the Compilation of a Mandatory Code of Practice for Emergency Preparedness and Response" has been developed and has been approved by the MHSC in January 2007. This Guideline has to be signed off by the Chief Inspector of Mines before it comes into effect.

The scope of this guideline relates to measures or procedures that are established to prepare to respond to and recover from the impact of emergencies but does not address any emergency prevention aspects.

This guideline addresses issues relating to hazard identification and risk assessment, detection and early warning systems, communication systems, first aid equipment and facilities, mine evacuation and escape strategy, rescue and response capabilities, management of emergencies and education, training and awareness.

This guideline will also incorporate four annexes namely:

- Refuge chambers;
- Establishing an emergency control centre, structure and procedure;
- Duties and responsibilities in the emergency control centre; and
- A schedule of additional references

The Annexure on refuge chambers is in principle the old Directive B5 [See Section 4.7.3]. The changes made only reflect the required legalities for CoPs under the MHSA.

4.7.3 Chief Inspectors Instructions and Directives

Directive B5 is a directive that was issued under the signature of the Chief Inspector of Mines on the 14th February 1994. The aim of Directive B5 is to ensure that refuge chambers are properly sited, constructed, equipped and maintained. The Directive also required Mine Managers to draft a CoP to ensure the effective construction, maintenance and preparedness system for such refuge chambers [Refer to Appendix E].

4.7.4 Guidance Notes

There are no current guidance notes related to refuge chambers.

4.8 Mining Qualifications Authority

The Mining Qualifications Authority [MQA] is a statutory body consisting of the State, Employer and Employee organizations in the mining industry. It was established in terms of the MHSA and is a registered Sector Education and Training Authority [SETA] for the Mining and Minerals Sector in terms of the Skills Development Act No 97 of 1998.

The MQA Standards Setting Unit is responsible for administering the functions of the Mining and Minerals Sector Standards Generating Body [M & M SGB]. The SGB is a stakeholder driven body with members from the following six primary stakeholders;

- The State
- Labor;
- Employers;
- Providers of Education and Training;
- Suppliers of Equipment & Services; and
- Mining Professional Associations.

Its main function is to design outcomes-based qualifications and write associated unit standards for registration on the National Qualifications Framework. The Framework is a guideline that presents the range of qualifications, skills programs and possible learnerships identified by the Sector to meet the competency needs in various fields and levels. This Framework is intended to ensure all the various training and development needs of the Sector are addressed at all required levels.

Under this framework various unit standards specifically referring to refuge chambers and escape and rescue training has been developed. These are [Refer to Appendices F, G, and H]:

- SAQA Unit standard 116533: Demonstrate basic knowledge and understanding of emergency preparedness and response;
- SAQA Unit standard 116513: Examine refuge chambers to ensure they are life sustainable; and
- SAQA Unit standard 48804: National Certificate: Occupational Safety, Hygiene and Environment.

4.9 Practicable Guidance from Current Legislation

4.9.1 Location and Deployment of Refuge Chambers

Regulation 24.20.2.1 states that "The manager shall see to it that there is a refuge chamber or other safe place in a mine or works are within easy reach of workmen and within the limits of protection afforded by a self rescuing device, in the event of an explosion, fire or other emergency".

This regulation is further supported by Directive B5 which requires that the manager [employer in the new guidelines] ensures that refuge chambers are positioned at an appropriate place [in areas free of combustible material or combustible material rendered inert in the new guidelines] and within an appropriate distance from the working places. Further due consideration must be given to factors such as:

- The travelling conditions from the workplace e.g. height, walking surface, gradient, possible disorientation, etc.
- The duration of the self-contained self-rescuers used on the mine.

4.9.2 Construction and Maintenance

Directive B5 gives clear guidance on the requirements for the construction of refuge chambers. These are as follows:

- Refuge chambers should be of robust construction and where there is a significant risk of explosions it must be able to withstand the effects of such an explosion.
- The size of the refuge chamber should be determined by the maximum number of persons likely to be present in the area served by the refuge chamber, with a minimum floor area of 0.6 m^2 per person.
- Life-sustaining services installed in the refuge chamber should be of fire resistant material or else be fire protected.
- A refuge chamber must be air tight and sealed in such a way so as to ensure a positive pressure that will make the refuge chamber inaccessible to air containing noxious smoke, fumes or gases.
- Refuge chambers should be provided with a man door, and where there is a significant risk of an explosion, a flexible type of door that would not be rendered ineffective in the event of an explosion should be considered.
- Refuge chambers should be provided with seating arrangements where practicable.
- Where applicable, such as at collieries, a surface borehole system, for the provisioning of respirable air to the refuge chamber, may be provided. Access requirements for equipment and vehicles to the borehole site must be taken into account.
- An identification system of refuge chambers must be implemented and must be clearly indicated on the inside and on the outside of the refuge chamber. Where a surface borehole system is used such corresponding identification must also be indicated at the borehole site on surface. This corresponding identification must be indicated on the Mine Rescue Plan contemplated in Regulation 17[19] [Refer to Appendix I].

In the new guidelines two additional requirements have been put in place. These are:

- Where the life-sustainability of a refuge chamber is dependent on compressed air, the supply to the inside of the refuge chamber should be tamper-free, with a control valve on the inside of the refuge chamber.
- Access arrangements into the refuge chamber should be such that it does not negatively affect the integrity or size of the refuge chamber.

Under the maintenance requirements Directive B5 requires that all refuge chambers be flushed and pressure tested before being commissioned and be repeated at appropriate intervals. Regulation 24.20.2.3 requires that refuge chambers be examined at intervals determined by the manager in consultation with the Inspector of mines, by persons appointed in writing by the manager for this purpose.

4.9.3 Minimum Life Sustaining Equipment Required

The minimum requirements of rescue chamber to be deemed life sustaining are captured in Regulations 24.20.2.2 (a), (b) and (c) under the Minerals Act and expanded in Directive B5.

Under this legislation a refuge chamber shall at least have the following in it:

- A supply of respirable air unless conditions are such that this is not required;
- Sufficient supply of potable water [at least two liters per person for 24 hours];
- First aid equipment consisting of at least a suitable stretcher, two blankets, and substantially constructed first aid box containing tourniquets, splints, bandages, individually wrapped sterile dressings and antiseptic solution;
- One or more notices on which are legibly printed in simple directions setting forth the approved procedures for the immediate treatment of cases of gassing, heat stroke, heat exhaustion, drowning and electric shock.
- Communication system with surface with relevant contact details of emergency personnel;
- Clearly visible reflective tape with symbolic sign indicating entrance to the refuge chamber;
- A conspicuous light with a reliable independent power supply, or any other physical means placed in such a position in the travelling way so as to indicate the location of the refuge chamber;
- An audible device positioned outside the refuge chamber that can be activated from the inside;
- Toilet facilities; and
- A notice board inside the chamber, displaying the correct procedure to be followed during occupation in an emergency, for example:
  - — Activate the ventilation arrangements;
  - — Activate the audible device;
  - — The most senior person to take charge of the operations and to contact the attendant at the surface control room or any other senior official on the mine;
  - — Take roll call;
  - — Remain calm and do not move around unnecessarily;
  - — Conserve lights. Keep only enough cap lamps on at any one time to provide sufficient illumination;
  - — Persons to remain in the refuge chamber until otherwise instructed by the official in charge at the control centre, or rescued; and
  - — Keep the door closed during occupation.

4.9.4 Emergency Preparedness and Training

Section 10 of the MHSA addresses the issue of training [Refer to Appendix J]. It states that an employer must provide employees with any information, instruction, training or supervision that is necessary to enable them to perform their work safely and without risk to health. No specific mention is made of required training specifically relating to refuge chambers in the MHSA regulations, guidelines, directives or notes. But as the risk of underground explosions and fires has been identified, the employer must provide employees with training regarding emergency response, which would imply the use of refuge chambers.

Under the National Qualifications Network the MQA has developed outcomes based unit standards for underground miners for which they must demonstrate competence. The unit standard titled "Demonstrate basic knowledge and understanding of emergency preparedness and response" require learners to demonstrate the required actions in case of an emergency. This includes the donning of self contained self rescuers and in some cases entering a place of safety [which could include a refuge chamber] and following the procedures. Specifically assessment criterion 4 requires learners to demonstrate the importance of adhering to the symbolic signs in terms of the consequences to health, safety and production.

5 IMPLEMENTATION OF REGULATORY GUIDELINES

As required by the MHSA Section 9[1] the employer at any underground mine may prepare and implement a CoP on any matter affecting the health or safety of employees and other persons who may be directly affected by activities at the mine. As the potential of an underground explosion of fire has been identified, and refuge chambers forms part of the emergency response strategy, a CoP specifically for refuge chambers need to drawn up by employers.

Between major and minor mining groups, it was found that the general content and extent of the refuge chamber CoPs was very similar. The only difference is that for the major mining houses the CoP is drawn up internally, and for minor groups external consultants are mostly used to develop their CoPs. This was also found by Van Achtenbergh and Gouws in 2003 [Van Achtenbergh and Gouws, 2003].

From discussions with the people responsible of drawing a refuge chamber CoP, it was found that the work done by Oberholzer in 1997 [Oberholzer, 1997] forms the basis of the inputs to the CoPs. Further to this, the variations observed in the reviewed CoPs is mostly concerned with the equipment used by the mine [e.g. duration of SCSR units, guidance equipment to the refuge chamber, refuge chamber locating devices, etc] and the general mining conditions [e.g. seam height, mining method, surface topology, etc].

At some mine of the mines the leaflet "ResQpacs – How to calculate safe traveling distances", published by the Research Organization of the Chamber of Mines of South Africa is used as guideline to determine the maximum distance of refuge chambers from working places [COMRO 1998].

The following sections will collate the findings of the review of the practicable aspects of the development of CoPs with specific reference to the following:

- Location and deployment of refuge chambers
- Construction and Maintenance
- Minimum life sustaining equipment required
- Emergency preparedness training

5.1.1 Location and Deployment of Refuge Chambers

From the CoPs reviewed if was found that refuge chambers are located at a maximum distance from working places of approximately 1 000 m. This maximum distance from the working places varied from 1 000 m to 660 m. A secondary consideration for locating a refuge chamber is the surface topography. Because South African coal seams are relatively shallow, the preferred method of supplying fresh air, communication, first aid, and sustenance is via surface boreholes. To be able to do this it is strived not to place refuge chamber under dams, structures or private property, were difficulties with access might be a problem. It is strived to place these rescue chambers near access roads and on mine property.

All refuge chambers are clearly marked on the escape and rescue plan and on surface were applicable.

Refuge chambers form an integral part of the escape and rescue strategy in the South African coal mining industry. The escape and rescue strategy developed consists of the following steps:

Don your self-contained-self-rescuer, then, [for most strategies] find the cache of long duration units stored at the production section waiting place, and then proceed to a place of safety.

Two options are available i.e., either reach a place of safety or alternatively reach a fresh air source. Firstly, if visibility is good and the self-contained-self-rescuer will allow you enough time to reach the shaft bottom [or surface], proceed to shaft bottom. Most South African collieries have been operating for decades, and typical distance from the mine shaft is in excess of 8 km – 10 km. This generally prohibits miners from reaching the mine shaft with their self-contained-self-rescuer units. If this is the case refuge chambers are generally deployed to provide places of safety until external help arrives in the form of proto teams or rescue drills from surface for extraction.

The rescue chambers can be permanent or intermediate [fixed or portable] in nature. The major difference between the two types, as reflected in the CoPs, is that permanent refuge chambers are connect to surface via a 160 mm to 200 mm borehole with a fan to force air into the refuge chamber and allow for life sustaining and rescue assistance to be rendered from surface 'indefinitely'. The intermediate refuge bays however have a limited supply of fresh air and life sustaining assistance is available. The majority of intermediate refuge bays are designed to supply life sustaining assistance for 24 hours, but in some cases 8 hours has been specified. This is based on the rescue strategy of the mine were rescue is expected tot take place within 8 to 24 hours of the incident by proto teams.

5.1.2 Construction and Maintenance

Of the reviewed CoPs all refuge chambers are constructed in the coal seam itself. There are various configurations which can be used. Refuge chambers can be either mined into the rib pillar [Figure 5.1], or it can be mined into a special refuge chamber pillar which is left in the general mining area [Figure 5.2], or it can be constructed between pillars left in the workings [Figure 5.3]. For this option, depending on the size, it can be sealed on four sides or on two.
In general it is recommended that when a wall is constructed, it not be placed between a return and intake road. This is to minimize the risk of air ingress due to intake and return air road way differential pressure.

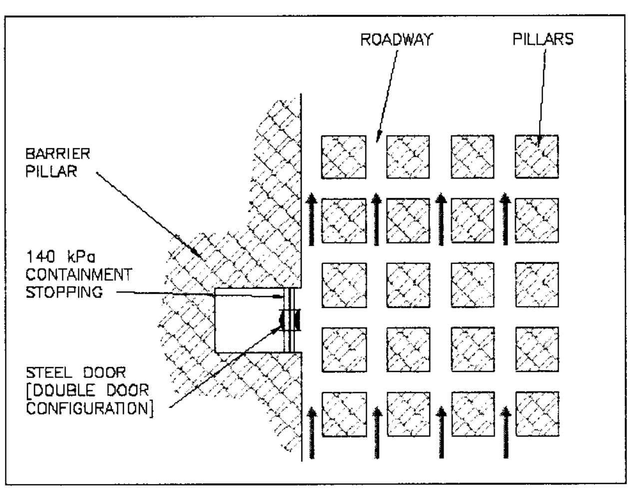

Figure 5.1 Typical configuration of refuge chamber in rib pillar.

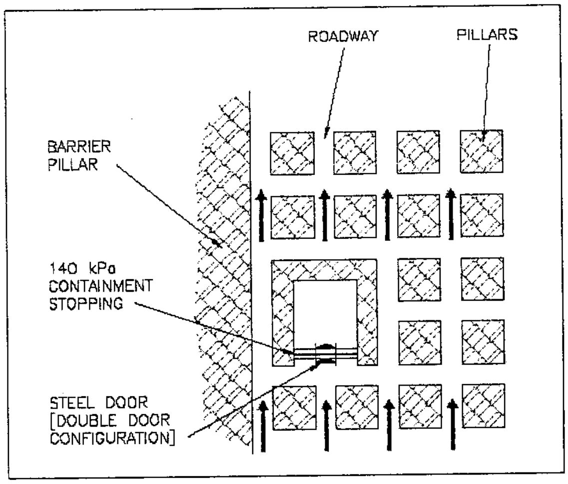

Figure 5.2 Typical configuration of refuge chamber in dedicated refuge chamber pillar.

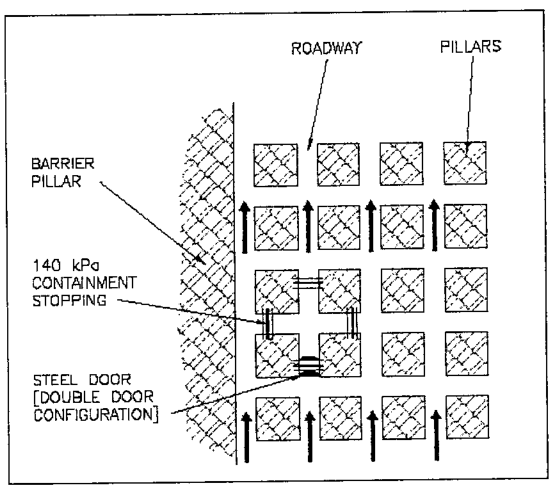

Figure 5.3 Typical configuration of refuge chamber between mined pillars

All the CoPs reviewed required that 140 kPa proof stoppings be used and that non-flammable materials be used for the construction. This is based on the finding of the work done by Oberholzer [Oberholzer, 1997]. Two types of wall construction methods were encountered. Firstly a normal brick wall is constructed and sand bags stacked against it at a 45 ° angle. Alternatively, any method approved by the United States Bureau of Mines is acceptable. This based on the work done by Van der Merwe and Cook in 2000 for SIMRAC [Van der Merwe and Cook, 2000]. The most common method used is the use of a masonry or concrete block construction.

The size of the rescue bay, according to Directive B5 must have a floor area of at least 0.6 m^2 per person. In the CoPs reviewed this value ranged from 1.0 m^2 to 1.5 m^2.

Entrance methods to the refuge chamber are via steel doors. Single and double door configurations were observed, and no clear preference could be determined. To assist miners to locate refuge chambers in low visibility conditions, three types of methods is generally used. These are ether audible locators which are permanently on, or visual locators which are permanently on, or physical locators, or a combination of the three. The audible locators consist of a siren located at the entrance to the refuge bay. Visual locators typically consist of a flashing light [typically red] at the entrance to the refuge chamber. The physical barrier consist of something hanging from the roof to shoulder height in the main travel way and the belt road. Conveyor belting, ropes, mesh wire, plastic sheets etc. has been observed. The principle is that miners will 'bump' into the 'barrier' and know that they must follow the barrier to the refuge chamber.

To further assist the integrity of refuge chambers most CoPs require that an area surrounding the entrance to the refuge bay be covered in stone dust to reduce the potential impact of a coal dust explosion in the region of the refuge bay.

All the requirements of the regulations and directives are met in the CoPs. It has to be mentioned that all the CoPs specifically require that emergency lighting be put in place in a refuge chamber.

Inspections of rescue chambers are done on a daily basis by shift personnel and monthly by mine management and the ventilation department. All maintenance required is done by mining personnel. For permanent refuge chambers the surface condition of the refuge chamber boreholes are regularly inspected to ensure no obstruction is present.

To assist in maintaining the integrity and the life sustaining ability of refuge chambers, most CoPs require that an emergency store be set-up on surface to ensure speedy maintenance to the rescue chambers.

5.1.3 Minimum Life Sustaining Equipment Required

For permanent rescue chambers [i.e. connected to surface] the minimum life sustaining equipment is specified by the regulations and Directive B5 [Refer to Section 4.9.3]. All the CoPs reflect these requirements.

To establish an adequate supply of respirable air, the permanent rescue chambers use an electric fan with back-up batteries to pull fresh air down the borehole into the rescue chamber. Air is expelled under this positive pressure into the mine via a 100 mm pipe no further than 300 mm from the roof of the rescue bay. To further enhance the life sustaining ability of permanent rescue chambers, some CoPs require that a dedicated response trailer be present at the shaft for rapid deployment to the surface location of the borehole. These trailers will typically contain further first aid equipment, communication equipment, fans, water, sustenance, etc.

For intermediate and portable refuge chambers adequate respirable air is ensured by typically three means. The first is to locate further caches of self-contained-self-rescuers in the chamber to ensure sufficient air supply for the duration the risk assessment requires the miners to be rescued. Secondly solid state oxygen generators are used in combination with body worn replaceable soda lime CO_2 filters [Refer to Figures 5.4 and 5.5]. The typical solid state oxygen generator used in the South African mining industry produces approximately 2 900 liters of chemical pure oxygen within 35-50 minutes.

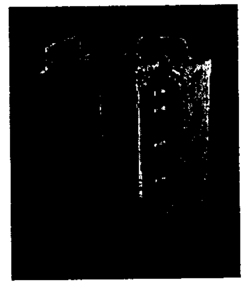

Figure 5.4 Solid State Oxygen Generator

The replaceable CO_2 filter cartridges can be used for up to 3 hours @ 90% efficiency [CO_2 <0.5%]

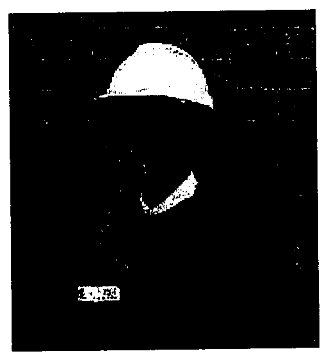

Figure 5.5 Replaceable CO_2 Filter cartridge.

Both these options are typically only considered as bridging strategies until permanent refuge chambers can be established or for remote underground operations or for small underground mining operations.

The third option is to use solid state oxygen generators in combination with CO_2 scrubbers and air conditioning units. Typically a 220V/24V battery backed oxygen generating and CO_2 scrubbing system designed to support 24 persons for 24 hours is used. This unit is commercially available and consists of 12 CO_2 filter canisters [10kg each] and 6-8 solid state oxygen generators. The SurvivAir-E was launched at the 1996 Electra Mining Africa Exhibition and was also awarded a gold medal during the April 1997, 25th International Exhibition of New Inventions, Technologies and New Products in Genèva, Switzerland. More than 100 units have been sold to the South African mining industry [Refer to Figure 5.6].

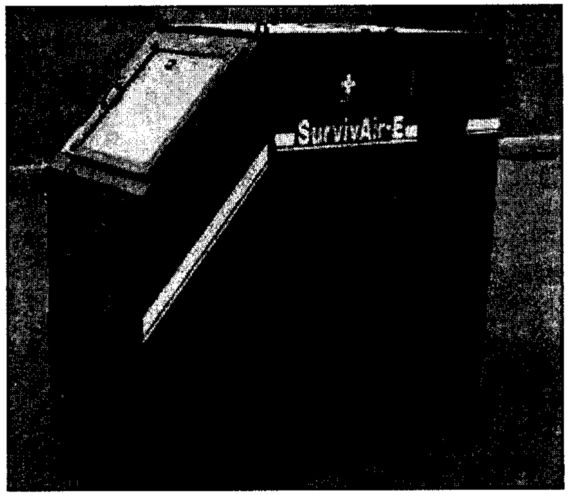

Figure 5.6 SurvivAir-E oxygen generation and carbon dioxide scrubbing unit

5.1.4 Emergency Preparedness and Training

Training specifically on the use of rescue bays is not specifically addressed in the Refuge Chamber CoPs. Mine personnel however do under go refresher training on all aspects of mine health and safety upon returning from annual leave. This includes emergency preparedness and escape strategies, which encompass the use of refuge chambers.

The new Guideline for Mandatory CoPs for Emergency Preparedness and Response [See section 4.7.2] has a specific section devoted to training and awareness. Section 8.1.5 of the new guideline requires training and awareness to be included in the CoP in order to ensure that all potentially affected persons are educated, trained and made aware on how to deal with emergencies. To achieve this, the guideline requires that the new CoPs must at least cover following:

- The content and frequency of such training [see also section 10[2][d] of MHSA];
- The procedures and appropriate actions to be taken in the event of an emergency, including simulated exercises;
- The correct procedures and applications on the use of emergency equipment;
- The actions required relating to the location and description of shutdown controls/lock out devices;
- Instructions in the use of belt-worn self-contained self-rescuers; and
- The locality of copies of the emergency procedures and instructions.

As part of the training for a general underground mining qualification, training is required by individuals to qualify as underground mine worker [Refer 4.8]. Part of this training includes the use of refuge chambers and the understanding of symbolic instructions in general.

6 IMPLEMENTATION OF GUIDELINES OF CODES OF PRACTICE

An assessment of the practical implementation of Emergency Preparedness and Response Codes of Practice, with specific focus on rescue chambers at major and minor mining operators was conducted. The assessment consisted of site visits, past experience and discussions with the Senior Inspector of Occupational Hygiene for the Witbank area [one the major coal fields in South Africa].

6.1 Practicable Application of Codes of Practices

6.1.1 Location and Deployment of Refuge Chambers

A major area of concern among major and minor mining operators is to keep the refuge chambers within 1 000m from the working areas.

The use of portable refuge chambers is not yet wide spread in the coal mining industry. One colliery deploys nine portable refuge chambers with success [no operational need required up to date]. Other collieries in the same mining group have each acquired one unit per shaft but it has not been fully deployed in the group yet. Discussions with various other operators [major and minor] regarding the use of portable refuge chambers revealed that they are either unaware or is currently unconvinced about the deployment of portable refuge chambers.

6.1.2 Construction and Maintenance

It was found that although the CoP in general requires 140 kPa stoppings to be constructed, the majority of refuge chambers do not comply with this standard.

Various entrance methods were observed for refuge chambers, ranging from single steel doors, to double steel doors, to pipe type entrances.

In general it was found that refuge chambers are well maintained and comply with the minimum requirements. It has to be noted that most refuge chambers has provision for emergency lighting. The biggest non compliance was supply of fresh potable water, as most of the refuge chambers do not have a dedicated water supply and replacing the potable water on regular basis is a cumbersome process.

6.1.3 Minimum Life Sustaining Equipment Required

In general the minimum life sustaining equipment is in good working order and inspections are carried out as per schedule and maintenance conducted.

6.1.4 Emergency Preparedness and Training

On mine refresher training was found to vary from mine to mine, even within mining houses. In general self-contained-self-rescuer training was conducted adequately. The only training directly related to refuge bays was periodic escape drills from the workplace to the refuge chambers.

Some mining houses make it compulsory for all employees to attend an explosion awareness program developed by the CSIR Kloppersbos explosion test facility [Refer to Appendix K]. As part of the training the learners are shown the condition of the atmosphere immediately after a coal dust explosion in a 200 m test gallery [Refer to Figure 6.1].

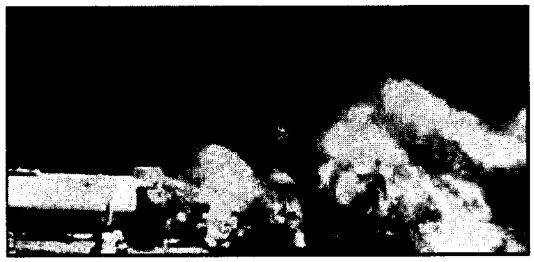

Figure 6.1 The coal dust explosion learners are exposed to during the CSIR explosion awareness program

7 PERFORMANCE ASSESSMENT OF RESCUE CHAMBERS

Apart from the required flushing and pressure testing of refuge chambers no specific standards applicable to the performance testing of refuge chambers could be identified.

8 MOBILE RESCUE CHAMBERS IN SOUTH AFRICAN MINING INDUSTRY

8.1 Suppliers of Mobile Rescue Chamber in South Africa

In South Africa there is one local supplier of mobile underground refuge chambers. The company is BroKrew Industrial [Pty] Ltd and they manufacture and maintain the Surviair-RRC. Their contact details can be found at www.brokrew.co.za. The company is ISO:9001:2000 accredited.

They supply mobile rescue chambers to the South African underground coal mining industry, South African underground platinum industry, South African tunnelling industry [Gautrain project], Australian copper mining industry and they also supply solid state oxygen generators to Canada.

The specifications of the flagship of the Survivair-RCC/Rescueair-ERB technology product range are as follows:

- Air tight, insulated / un-insulated steel constructed refuge chamber
- CO/CO_2 scrubbing system
- Air Conditioner/de-humidifier system
- Battery Backed AC Power Inverter System
- Survivair Oxygen Generators

Options for the Surviviar-RCC include:

- 3.4m 8 Person/12 Hour unit
- 3.4m 12 Person/18 Hour unit
- 4.5m 14 Person/24 Hour unit

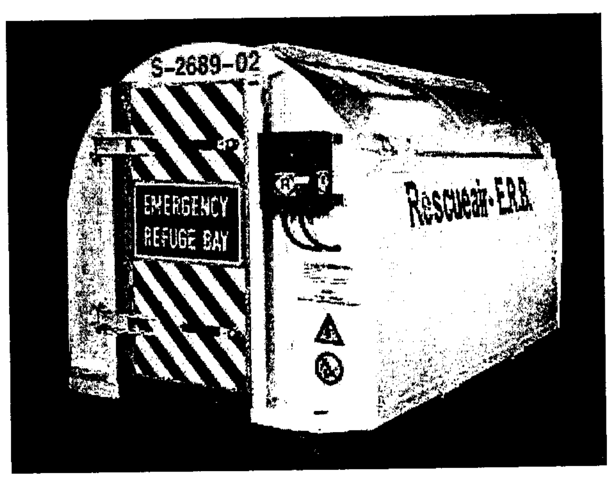

Figure 8.1 The Surviviar-RCC/Rescueair-ERB

The product range also includes a low seam Survivair-RCC/Rescueair-ERB. The low seam version has the same operating specifications as the flagship unit but have different dimensions to be able to be deployed in low seam applications. The dimensions are 1.7 m H x 2.0 m W x 6 m L. Options include the following:

- 3.4m 12 Person/18 Hour unit
- 4.5m 14 Person/24 Hour unit
- 6.0m 16 Person/24 Hour unit

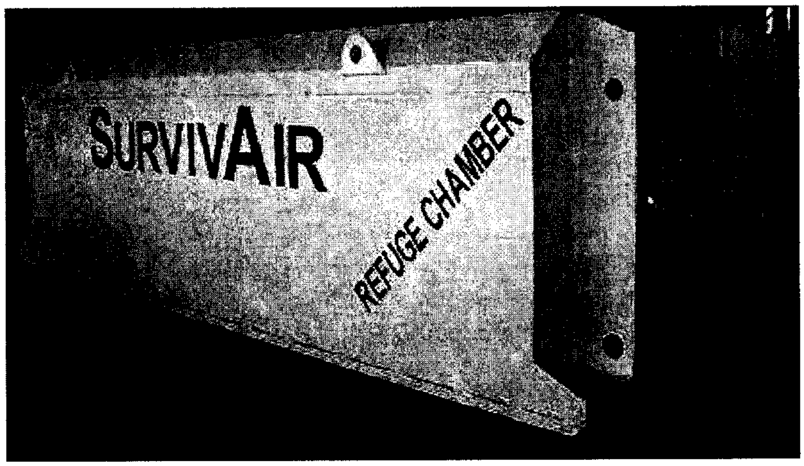

Figure 8.2 The low seam Survivair-RCC/Rescueair-ERB

8.2 The Survivair Mobile Rescue Chamber

The Survivair mobile refuge chamber was developed in South Africa from 1987 to 1997 in a joint venture between BroKrew and Naschem, a Division of Denel. The approach was to start off with a low tech solution [Appendix K] and increase the complexity until a life sustaining unit was developed.

The initial requirements for the mobile rescue chambers were set as follows:

- Self sufficient to ensure that 12 workers have respirable air for a period of 24 hours [respirable air = oxygen > than 18% and CO_2 < 0.5%].
- Ensure an appropriate environment in terms of temperature and relative humidity [20 – 25°C en 60 – 80% RH)
- Durable construction to handle underground seismic activity and explosions.
- Supply visual and audible alarms for easy identification.
- Modular design for easy transportation and adaptability to increase size as required.
- Entrance to the refuge chamber through an air curtain.
- Must be able to operate in an irrespirable atmosphere.
- Must be designed to ensure that a positive pressure is maintained inside the refuge chamber so as to prevent the ingress of noxious gases or fumes.
- Must be designed to be air tight.
- Must be equipped with water, first aid equipment and toilet facilities.
- Equipped with a means of communication to surface of the mine.
- To be mounted on ski's to ensure portability.
- Easy access to be guaranteed.
- Must be easy to operate.
- Independent of external power supply and should be able to function independently.
- Must be sited as close to the working place as possible [within non-flame proof distance].
- Must have a fire rating of 1 hour.

The basic concept was to design an air tight chamber and use solid state oxygen generators to replenish oxygen and use a soda lime scrubber to remove metabolically generated carbon dioxide [Venter *et al* 1999].

In developing the life sustaining design parameters standards from NASA, Canada Ontario Province, Australia and applicable US standards were consulted. After exhaustive testing, including human subject evaluation, design parameters for oxygen consumption, metabolic carbon dioxide generation and heat generation was developed. Based on this the following guidelines can be used when developing a life sustaining system in an airtight chamber [De Klerk, 2007 and Venter, 2007]:

- Initial oxygen concentration 20.95 %
- Initial Carbon Dioxide 300 ppm
- Carbon Dioxide maximum 5000 ppm
- Oxygen minimum 19 %
- 30 Liters of oxygen/person/hour
- 24 Liters Carbon Dioxide/person/hour
- Heat produced 150-250 Watt per person

Apart from the life sustaining standards various other regulations were consulted. These included:

- Public Transport Guidelines for Seating Arrangements
- Australian Electrical Standards [The unit is not intrinsically safe nor flameproof]

The unit is supplied to the mines with a maintenance manual and user manual. Typically a service contract will be entered into, where the units are serviced every three years with the main reason being battery life and general equipment maintenance.

9 LIST OF RELEVANT FURTHER INFORMATION SOURCES

1. The Mine Health and Safety Act of 1996 can be found at http://www.acts.co.za/mhs/index.htm
2. The MQA website is http://www.mqa.org.za
3. DME Website on Guidelines is http://www.dme.gov.za/mhs/documents.stm
4. The SIMRAC website can be found at http://www.simrac.co.za/. Relevant reports can be found in the Explosions and Fires and Special Projects sections.

10 REFERENCES

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2. De Klerk C. Mines Rescue Services [South Africa]. *Personal communication July 2007.*
3. Oberhozer JW. Assessment of refuge bay designs in collieries. *COL 115 SIMRAC Final Research Report, January 1997.*
4. Van Achtenbergh A and Gouws MJ. Prevention based health and safety regulatory mechanisms – the South African experience, *ISSA/Chamber of Mines Conference 2003 – Mines and Quarries: Prevention of Occupational Injury and Disease, 2003.*
5. Van der Merwe JN and Cook AP. Design, construction and testing of underground seals. *COL 502 SIMRAC Final Research Report, January 2000.*
6. Venter JM *et al.* Portable refuge chambers: Aid or tomb in underground escape strategies. *Journal of the Mine Ventilation Society of South Africa, January/March 1999.*
7. Venter JM. Naschem. *Personal communication, September 2007.*

APPENDIX A: MINE HEALTH AND SAFETY ACT, 1996 SCHEDULE 4 - TRANSITIONAL PROVISIONS

1. Any health and safety standard which, immediately prior to the commencement of this Act, was incorporated under the provisions of the Minerals Act or the regulations made under that Act is deemed to be a health and safety standard incorporated under this item.
2. A certificate of fitness issued under the provisions of the Occupational Diseases in Mines and Works Act, 1973 (Act No. 78 of 1973), which was valid immediately before the commencement of this Act shall be deemed to be sufficient proof that the employee is fit to perform work until the certificate is cancelled or expires.
3. A declaration in respect of any work which has been declared under the Occupational Diseases in Mines and Works Act, 1973 (Act No. 78 of 1973), to be risk work at controlled mines is deemed to be a declaration made under section 76(1) of this Act and remains in force until the declaration is withdrawn or superseded under this Act.
4. Any regulation made or deemed to be made under the Minerals Act that relate to health and safety issues that can be regulated under this Act, may be amended under this Act and remains in force until repealed under this Act.
5. To the extent that it grants exemptions from the operation of a provision similar to a provision of this Act, an exemption is deemed to have been granted under section 79 if-
   a. it was granted under the provisions of the Minerals Act; and
   b. it is still in force when this Act commences.
6. Section 85 does not apply to an employee employed at any mine immediately before the commencement of that section.

APPENDIX B: MINE HEALTH AND SAFETY ACT, 1996, CHAPTER 4, TRIPARTITE INSTITUTIONS 41 - ESTABLISHMENT OF TRIPARTITE INSTITUTIONS

1) A Mine Health and Safety Council is hereby established to advise the Minister on health and safety at mines.

2) The following permanent committees of the Council are hereby established--
   a) the Mining Regulation Advisory Committee;
   b) the Mining Occupational Health Advisory Committee; and
   c) the Safety in Mines Research Advisory Committee.

3) A Mining Qualifications Authority is hereby established to advise the Minister on--
   a) qualifications and learning achievements in the mining industry to improve health and safety standards through proper training and education;
   b) standards and competency setting, assessment, examinations, quality assurance and accreditation in the mining industry; and
   c) proposals for the registration of education and training standards and qualifications in the mining industry on the National Qualifications Framework referred to in the South African Qualifications Authority Act, 1995 (Act No. 58 of 1995).
   (The South African Qualifications Authority Act provides for a National Qualifications Framework which aims to enhance the quality of education and training.)

APPENDIX C: MINE HEALTH AND SAFETY ACT, 1996 CHAPTER 2, SECTION 9 - CODES OF PRACTICE

1) Any employer may prepare and implement a code of practice on any matter affecting the health or safety of employees and other persons who may be directly affected by activities at the mine.

2) An employer must prepare and implement a code of practice on any matter affecting the health or safety of employees and other persons who may be directly affected by activities at the mine if the Chief Inspector of Mines requires it.

3) A code of practice required by the Chief Inspector of Mines must comply with guidelines issued by the Chief Inspector of Mines.

4) The employer must consult with the health and safety committee on the preparation, implementation or revision of any code of practice.

5) The employer must deliver a copy of every code of practice prepared in terms of subsection (2) to the Chief Inspector of Mines.

6) The Chief Inspector of Mines must review a code of practice of a mine if requested to do so by a registered trade union with members at the mine, or a health and safety committee or a health and safety representative at the mine.

7) At any time, an inspector may instruct an employer to review any code of practice within a specified period if that code of practice--

a) does not comply with a guideline of the Chief Inspector of Mines; or
b) is inadequate to protect the health or safety of employees.

APPENDIX D: MINERALS ACT REGULATIONS (IN FORCE IN TERMS OF SECTION 4 OF THE MHSA)

24.20.2.2 For the purposes of these regulations -

(a) "refuge chamber" 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 chamber –

(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 the first aid equipment referred to in regulation 24.1.1;

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

(v) equipped with an apparatus referred to in regulation 24.6; and situated where possible, in an area free of combustible material;

(b) "other safe place" shall mean –

(i) the surface of the mine or works; or

(ii) an intake airway commencing from the surface of the mine or works, which contains no combustible material or in which all combustible material has been rendered fire-resistant and in which all combustible material in quantities sufficient to endanger or likely to endanger the safety of somebody is conveyed during the working shifts; or

(iii) a selected place in the underground working where additional self-rescuing devices approved by the Chief Inspector are stored ready for use, sufficient in number to provide for the number of persons likely to make use of such devices, and of adequate duration to reach refuge chamber or other safe place; and

(c) "respirable air" shall mean air, the quality of which complies with the provision of regulation 10.6.6 [repealed and replaced by Chapter 22 Tables Occupational Exposure/Control Limits] and is not contaminated by another substance which is harmful or likely to be harmful.

"self contained rescuing device" shall mean a device which provides respirable air, independent of the surrounding atmosphere to protect the wearer from exposure to irrespirable air.

24.1.1 Where the number of persons employed on surface including opencast workings, at any one time is 300 or less, there shall be kept in a readily accessible, clean and dry place a suitable stretcher, provided with 2 blankets, and substantially constructed first aid box containing tourniquets, splints, bandages, individually wrapped sterile dressings and antiseptic solution.

24.6 One or more notices on which are legibly printed in both official languages simple directions setting forth the approved procedures for the immediate treatment of cases of gassing, heat stroke, heat exhaustion, drowning and electric shock shall be posted up in a conspicuous place in every change house and in every first aid room.

APPENDIX E: DIRECTIVE B 5

81/172892
(Z 28)

DEPARTMENT OF MINERAL AND ENERGY AFFAIRS

DIRECTIVE NO	:	B 5 . EFFECTIVE DATE: 14 February 1994
SUBJECT	:	A Guideline For The Siting, Construction, Equipping And Maintaining Of Refuge Bays
SCOPE	:	This directive is applicable to all mine safety and health enforcement personnel and Managers of all mines with underground workings for guidance in the compliance with the provisions contained in the Minerals Act, Regulation 24.20.2.1 to ensure that refuge bays are properly sited, constructed, equipped and maintained.
PURPOSE	:	The purpose of this directive and addendum is to guide regional directors and mine management in the compilation and approval of a code of practice relating to refuge bays.
DIRECTIVE	:	Regional Directors must request a code of practice in terms of Section 34(1) of the Minerals Act, to be drawn up by managers of all mines where refuge bays are legally required, in order to ensure an effective construction, maintenance and preparedness system for such refuge bays.
AUTHORITY	:	Government Mining Engineer
ISSUING OFFICE	:	Director General
DISTRIBUTION	:	Government Mining Engineer

Chief Directors:	Mining Safety Mining Equipment Safety Mine Environmental Control and Rehabilitation
Directors:	Mining Safety Mining Equipment Safety Mine Environmental Control
Regional Directors:	PWV Region Northern Transvaal Region Eastern Transvaal Region Western Transvaal Region Natal Region Orange Free State Region Eastern Cape Region Northern Cape Region Western Cape Region

GOVERNMENT MINING ENGINEER
DIRECTOR GENERAL
S:\TTERT\AH\REFBAYS

GUIDELINES FOR REFUGE BAYS

1. OBJECTIVE

To provide a guideline and general framework for the siting, construction, equipping and maintenance of refuge bays.

2. SITING / LOCATION

The position of a refuge bay must be determined by the manager in charge of the section in consultation with his Environmental Control Officer/Ventilation Official (Person appointed in terms of Regulation 2.16.1.1), and to be positioned at an appropriate distance from the working places, with due consideration given to factors such as:

(i) the travelling conditions from the workplace e.g. height, walking surface, gradient, possible disorientation, etc.

(ii) the capacity of the self contained rescuing device apparatus used on the mine.

3. CONSTRUCTION / DESIGN

3.1 Refuge bays must be of robust construction and where there is a high risk of explosions it must be able to withstand the effects of such an explosion.

3.2 Refuge bays must be designed for the maximum number of persons in the section that it will serve, with a minimum floor area of 0,6 m^2 per person.

3.3 Service piping to the refuge bay should be of fire resistant material or else be fire protected.

3.4 Bay to be air leak proof, sealed in such a way so as to ensure a positive pressure when in use.

3.5 Provided with an access mandoor, and where there is a high risk of an explosion, a flexible type of door should be considered.

3.6 Provided with seating arrangements.

3.7 Where applicable an effective surface borehole with proper surface site installations, e.g. ventilation fans may be provided, taking into account access requirements for equipment and vehicles to the borehole site.

3.8 For identification and control purposes, the refuge bay must be clearly and suitably numbered both on the inside and on the outside of the bay and on surface, where applicable, for easy identification. Those numbers must also appear on the corresponding refuge bays indicated on the Mine Rescue Plan.

4. EQUIPMENT / FACILITIES

4.1 Supply of potable water (A minimum of 2 litres per person for 24 hours is recommended).

4.2 A telephone for communication between surface and underground. The appropriate emergency telephone numbers must be displayed.

4.3 A clearly visible reflective type "Refuge Bay" symbolic sign to be displayed at the entrance to the bay.

4.4 A conspicuous light with a reliable power supply or any other physical means placed in such a position in the travelling way so as to indicate the location of the refuge bay.

4.5 An audible signalling device positioned outside the bay and activated from the inside.

4.6 Toilet facilities

4.7 First aid equipment. May also be used as an optional first aid station.

4.8 A notice board inside the bay, displaying the correct procedure to be followed during occupation in an emergency, for example:

- Activate the ventilation arrangements.
- Activate the audible signalling device.
- The most senior person to take charge of the operations and to contact the attendant at the surface control room or any other senior official on the mine.
- Take roll-call.
- Remain calm and do not move around unnecessarily.
- Conserve lights. Keep only enough caplamps on at any one time to provide sufficient illumination.
- Persons to remain in bay until otherwise instructed by the official in charge at the control room, or rescued.
- Keep door closed during occupation.

5. VENTILATION ARRANGEMENTS

A reliable source of respirable air must be supplied to the bay so as to ensure proper flushing and create a positive pressure. Where compressed air is used an arrangement for silencing must be provided.

6. MAINTENANCE / INSPECTIONS

6.1 All equipment and facilities as outlined in items 4.1 through 4.8 and paragraph 5 shall be routinely inspected by persons designated and appointed for this purpose to ensure that the refuge bay and facilities are in constant good order. Records of reports must be kept.

6.2 Flushing and pressurization tests must be conducted on all refuge bays before being commissioned.

7. ESCAPE ROUTES AND EVACUATION DRILLS

7.1 Escape routes to refuge bays and alternative fresh air routes shall be clearly marked, on a plan to be kept on surface and up-dated monthly by a person appointed by the Manager in consultation with the Environmental/Ventilation Officer (Person appointed under Regulation 2.16.1.1).

7.2 These routes must be clearly marked underground with the recognised symbolic signs or other physical means.

7.3 Supervisors shall ensure that all workers are familiar with these routes.

7.4 Management shall ensure that all persons are adequately trained in the evacuation drill and procedures in event of emergencies. Records to be kept of all drills performed.

8. CONTROL / REVIEW

Refuge bay procedures, the locality of bays and escape strategies are to be reviewed at intervals determined by the Manager in charge.

SITTERT\AM\BAYGUID

APPENDIX F: UNIT STANDARD FOR UNDERSTANDING OF BASIC EMERGENCY PREPAREDNESS AND RESPONSE

SAQA

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SOUTH AFRICAN QUALIFICATIONS AUTHORITY

REGISTERED UNIT STANDARD:

Demonstrate basic knowledge and understanding of emergency preparedness and response

SAQA US ID	**UNIT STANDARD TITLE**		
116533	Demonstrate basic knowledge and understanding of emergency preparedness and response		
SGB NAME		**REGISTERING PROVIDER**	
SGB Occupational Health and Safety			
FIELD		**SUBFIELD**	
Field 09 - Health Sciences and Social Services		Preventive Health	
ABET BAND	**UNIT STANDARD TYPE**	**NQF LEVEL**	**CREDITS**
Undefined	Regular-Fundamental	Level 2	2
REGISTRATION STATUS	**REGISTRATION START DATE**	**REGISTRATION END DATE**	**SAQA DECISION NUMBER**
Reregistered	2007-08-07	2010-08-07	SAQA 0160/05

PURPOSE OF THE UNIT STANDARD

This unit standard requires learners to demonstrate basic knowledge an understanding of emergency preparedness and response. Learners credited with this unit standard are capable of:

- Discussing the different types of emergencies that may be encountered in the workplace
- Explaining emergency preparedness and demonstrating response appropriate to the situation

LEARNING ASSUMED TO BE IN PLACE AND RECOGNITION OF PRIOR LEARNING

The Unit Standard outcomes and credits are based on the assumption that learners attempting this Unit Standard can already read, write and communicate at ABET 3 or equivalent.

UNIT STANDARD RANGE

Specific range statements are provided in the body of the unit standard where they apply to particular specific outcomes or assessment criteria. Note: Emergencies must include: Floods, Fires, Explosions, Seismic events, power failures, Emission of gas, sudden release of gases, Chemical incidents, and equipment failure.

UNIT STANDARD OUTCOME HEADER

N/A

Specific Outcomes and Assessment Criteria:

SPECIFIC OUTCOME 1
Discuss different types of emergencies that may be encountered in a workplace.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
Different types of emergencies that may be encountered in a workplace are listed and are according to specified requirements.

ASSESSMENT CRITERION 2
Effects that these emergencies in the workplace may have on worker health and safety is described in accordance with specified requirements.

ASSESSMENT CRITERION 3
The purpose of warning, mandatory, statutory and informative signs is explained and is according to specified requirements.

ASSESSMENT CRITERION 4
The importance of adhering to the symbolic signs is explained in terms of the consequences to health, safety and production.

SPECIFIC OUTCOME 2
Explaining emergency preparedness and demonstrating response appropriate to the situation.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
Explanation of immediate personal action to be taken, in the event of an emergency, is in accordance with specified requirements.

ASSESSMENT CRITERION RANGE
Personal action includes: withdrawal, warning of other workers, reporting, first aid treatment and donning of self-contained-self-rescuer.

ASSESSMENT CRITERION 2
Emergency preparedness is explained in terms of specified requirements.

ASSESSMENT CRITERION 3
Explanation of restricted and confined areas, traveling ways and escape routes is according to specified requirements.

ASSESSMENT CRITERION 4
Demonstrations of actions to be taken during prescribed situations confirm understanding of specified requirements.

UNIT STANDARD ACCREDITATION AND MODERATION OPTIONS
Assessment of learner achievements takes place at providers accredited by a relevant ETQA (RSA, 1998b) for the provision of programs that result in the outcomes specified for this unit standard. Anyone assessing a learner against this unit standard must be registered as an assessor with a relevant ETQA. Any institution offering learning that will enable achievement of this unit standard must be accredited as a provider with a relevant ETQA. The relevant ETQA according to the moderation guidelines and the agreed ETQA procedures will oversee moderation of assessment and is responsible for moderation of learner achievements of learners who meet the requirements of this unit standard.

UNIT STANDARD ESSENTIAL EMBEDDED KNOWLEDGE
Essential embedded knowledge will be assessed through assessment of the specific outcomes in terms of the stipulated assessment criteria. Learners are unlikely to achieve all the specific outcomes, to the standards described in the assessment criteria, without knowledge of the listed embedded knowledge. This means that for the most part, the possession or lack of the knowledge can be directly inferred from the quality of the learner's performance. Where direct assessment of knowledge is required, assessment criteria have been included in the body of the unit standard.
Credited learners understand and can explain:

- Legal and specified requirements
- The different types of emergencies that may be encountered in the workplace

• Emergency preparedness

UNIT STANDARD DEVELOPMENTAL OUTCOME
N/A

UNIT STANDARD LINKAGES
N/A

Critical Cross-field Outcomes (CCFO):

UNIT STANDARD CCFO IDENTIFYING
Identify and solve problems and make decisions using critical and creative thinking. Note: The ability of the learner to interpret emergency situations contributes to his/her problem solving skills.

UNIT STANDARD CCFO WORKING
Work effectively with others as members of a team, group, organisation or community. Note: The ability and willingness of the learner to accept, interpret and delegate work instructions correctly, when and if required, in an appropriate manner indicates that he/she can work effectively as a team member in the bigger organisational structure.

UNIT STANDARD CCFO ORGANISING
Organize and manage themselves and their activities responsibly and effectively. Note: Competence in applying acquired knowledge will indicate that the learner can organize and manage activities in his/her working environment.

UNIT STANDARD CCFO COLLECTING
Collect, analyze, organize and critically evaluate information. Note: The ability of the learner to evaluate and interpret situations will indicate proficiency.

UNIT STANDARD CCFO COMMUNICATING
Communicate effectively, using visual, mathematical and / or language skills in the modes of oral and / or written presentations. Note: The ability of the learner to use visual, mathematical and language skills will indicate his/her effectiveness to communicate information in the modes of oral and written presentations.

UNIT STANDARD CCFO SCIENCE
Use science and technology effectively and critically showing responsibility towards the environment and health of others.

UNIT STANDARD CCFO DEMONSTRATING
Demonstrate an understanding of the world as a set of related systems by recognizing that problem-solving contexts do not exist in isolation. Note: The ability of the learner to identify and refer anomalous behaviour to a specialist confirms understanding that a specific observation, inference, action or decision can have an interrelated effect.

UNIT STANDARD ASSESSOR CRITERIA
Assessors should keep the following principles in mind when designing and conducting assessments against this unit standard:

• Focus the assessment activities on gathering evidence in terms of the main outcome expressed in the title to ensure assessment is integrated rather than fragmented. Remember we want to declare the learner competent in terms of the title. Where assessment at title level is unmanageable, then focus assessment around each specific outcome, or groups of specific outcomes.

• Make sure evidence is gathered across the entire range, wherever it applies. Assessment activities should be as close to the real performance as possible, and where simulations or role-plays are used, there should be supporting evidence to show the learner is able to perform in the real situation.

• Do not focus the assessment activities on each assessment criterion. Rather make sure the assessment activities focus on outcomes and are sufficient to enable evidence to be gathered around all the assessment criteria.

• The assessment criteria provide the specifications against which assessment judgements should be made. In most cases, knowledge can be inferred from the quality of the performances, but in other cases, knowledge and understanding will have to be tested through questioning techniques. Where this is required, there will be assessment criteria to specify the standard required.

• The task of the assessor is to gather sufficient evidence, of the prescribed type and quality, as specified in this unit standard, that the learner can achieve the outcomes again and again and again. This means assessors will have to judge how many repeat performances are required before they believe the performance is reproducible.

• All assessments should be conducted in line with the following well documented principles of assessment: appropriateness, fairness, manageability, integration into work or learning, validity, direct, authentic, sufficient, systematic, open and consistent.

UNIT STANDARD NOTES

Specified requirements include legal and site-specific requirements and are contained in one or more of the following documents:

Legal requirements:

- OHS Act and Regulations 85 / 1993
- Mine Health and Safety Act and Regulations 29/1996
- Guideline for mandatory Codes of Practice

Site-specific requirements:

- Managerial instructions
- Codes of Practice
- Company Standards
- Standard Task Procedures
- Health Management Programme
- Risk Assessment Documentation
- Working Guides
- Manufacturers` specifications.

QUALIFICATIONS UTILISING THIS UNIT STANDARD:

	ID	QUALIFICATION TITLE	LEVEL	STATUS	END DATE
Core	48804	National Certificate: Occupational Safety, Hygiene and Environment	Level 2	Reregistered	2010-08-07
Core	21842	National Certificate: Surface Mining Rock breaking	Level 2	Reregistered	2009-11-07
Core	57121	National Certificate: Rock breaking: Quarrying	Level 3	Registered	2009-11-16
Elective	58722	National Certificate: Engineering Fabrication	Level 2	Registered	2010-08-16

APPENDIX G: UNIT STANDARD FOR REFUGE CHAMBER EXAMINATION

SAQA

SOUTH AFRICAN QUALIFICATIONS AUTHORITY
REGISTERED UNIT STANDARD:

Examine refuge chambers to ensure they are life sustainable

SAQA US ID	**UNIT STANDARD TITLE**		
116513	Examine refuge chambers to ensure they are life sustainable		
SGB NAME		**REGISTERING PROVIDER**	
SGB Occupational Health and Safety			
FIELD		**SUBFIELD**	
Field 09 - Health Sciences and Social Services		Preventive Health	
ABET BAND	**UNIT STANDARD TYPE**	**NQF LEVEL**	**CREDITS**
Undefined	Regular-Fundamental	Level 2	1
REGISTRATION STATUS	**REGISTRATION START DATE**	**REGISTRATION END DATE**	**SAQA DECISION NUMBER**
Reregistered	2007-08-07	2010-08-07	SAQA 0160/05

PURPOSE OF THE UNIT STANDARD
This unit standard requires learners to be able to examine refuge chambers to ensure that they are life sustainable. Learners credited with this unit standard are capable of:
- Describing the specified requirements pertaining to the examination of refuge chambers
- Preparing to examine refuge chambers
- Examine refuge chambers
- Performing post refuge chamber examination activities

LEARNING ASSUMED TO BE IN PLACE AND RECOGNITION OF PRIOR LEARNING
The ability to read and write at ABET level 3 or equivalent will facilitate better understanding and demonstrate proficiency in this unit standard.

UNIT STANDARD RANGE
Specific range statements are provided in the body of the unit standard where they apply to particular specific outcomes or assessment criteria.

UNIT STANDARD OUTCOME HEADER
N/A

Specific Outcomes and Assessment Criteria:

SPECIFIC OUTCOME 1
Describe the specified requirements pertaining to the examination of a refuge chamber.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
Explanation of the function of a refuge chamber is consistent with specified requirements.

ASSESSMENT CRITERION 2
The description, equipment and operation of a refuge chamber are consistent with specified requirements.

ASSESSMENT CRITERION 3
The consequences of not examining a refuge chamber are explained in accordance with specified requirements.

SPECIFIC OUTCOME 2
Prepare to examine the refuge chambers.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
The examination and use of the required personal protective equipment is according to specified requirements.

ASSESSMENT CRITERION 2
The importance of examination and use of the required personal protective equipment is explained in terms of the consequences to health and safety.

ASSESSMENT CRITERION 3
The selection of the relevant refuge chamber to be examined, reviewing of previous examination results and confirmation of access route is consistent with specified requirements.

ASSESSMENT CRITERION 4
The required instruments are inspected and verified according to specified requirements.

ASSESSMENT CRITERION 5
The importance of inspecting the instruments is explained in terms of the consequences to health and safety.

ASSESSMENT CRITERION 6
The preparation work is performed in a manner that fosters teamwork and avoids conflict.

SPECIFIC OUTCOME 3
Examine refuge chamber.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
The route to the refuge chamber is examined and hazards and risks pertaining to health and safety are dealt with according to specified requirements.

ASSESSMENT CRITERION 2
The importance of examining the route and dealing with hazards and risks are explained in terms of the possible consequences to health and safety.

ASSESSMENT CRITERION 3
The refuge chamber is examined and hazards and risks pertaining to health and safety are dealt with according to specified requirements.

ASSESSMENT CRITERION 4
The importance of examining the refuge chamber and dealing with sub standard conditions is explained in terms of the possible consequences to health and safety.

ASSESSMENT CRITERION 5
The measurements of the environmental conditions in the refuge chamber are performed according to specified requirements.

ASSESSMENT CRITERION 6
The results of the examination and measurements are recorded according to specified requirements.

ASSESSMENT CRITERION 7
The examination is done in a manner that fosters teamwork and avoids conflict.

SPECIFIC OUTCOME 4
Perform post examination activities.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
Reports are complete, accurate, in the required format and submitted to the designated personnel on time.

ASSESSMENT CRITERION 2
The measuring equipment are cleaned and stored according to specified requirements.

ASSESSMENT CRITERION 3
Defective measuring equipment is dealt with according to specified requirements.

UNIT STANDARD ACCREDITATION AND MODERATION OPTIONS

UNIT STANDARD ESSENTIAL EMBEDDED KNOWLEDGE
Essential embedded knowledge will be assessed through assessment of the specific outcomes in terms of the stipulated assessment criteria. Learners are unlikely to achieve all the specific outcomes, to the standards described in the assessment criteria, without knowledge of the listed embedded knowledge. This means that for the most part, the possession or lack of the knowledge can be directly inferred from the quality of the learner`s performance. Where direct assessment of knowledge is required, assessment criteria have been included in the body of the unit standard.

Credited learners understand and can explain:

- Legal and site-specific requirements
- The function of a refuge chamber
- Equipment and operation of a refuge chamber
- The consequences of not examining a refuge chamber
- The examination and use of the required personal protective equipment
- The importance of examination and use of the required personal protective equipment
- The selection of the relevant refuge chamber to be examined, reviewing of previous examination results and confirmation of access route
- How the refuge chamber is examined and hazards and risks pertaining to health and safety are dealt with
- The importance of examining the refuge chamber and dealing with sub standard conditions
- How the measurements of the environmental conditions in the refuge chamber are performed
- How the results of the examination and measurements are recorded
- How defective measuring equipment is dealt with

UNIT STANDARD DEVELOPMENTAL OUTCOME
N/A

UNIT STANDARD LINKAGES
N/A

Critical Cross-field Outcomes (CCFO):

UNIT STANDARD CCFO IDENTIFYING
Identify and solve problems and make decisions using critical and creative thinking. Note: The ability of the learner to identify problems in terms of refuge chambers and making recommendations indicates that he/she can solve problems.

UNIT STANDARD CCFO WORKING
Work effectively with others as a member of a team/group/organization/community. Note: The ability and willingness of the learner to accept, interpret and delegate work instructions correctly, if and when required, in an appropriate manner indicates that he/she can work effectively as a team member in the bigger organizational structure.

UNIT STANDARD CCFO ORGANISING

Organise and manage oneself and one`s activities responsibly and effectively. Note: The identification of the correct instruments and procedure will indicate that the learner can organise and manage activities in his/her working environment.

UNIT STANDARD CCFO COLLECTING
Collect, organise and evaluate information. Note: The ability of the learner to collect information on refuge chambers at specified locations will indicate proficiency in collecting, organising and evaluating information.

UNIT STANDARD CCFO COMMUNICATING
Communicate effectively using visual, mathematics and language skills in the modes of oral and written presentations. Note: The ability of the learner to communicate problems concerning refuge chambers will indicate his/her effectiveness to communicate information.

UNIT STANDARD CCFO SCIENCE
Use science and technology effectively and critically (showing responsibility towards the environment and health of others). Note: The ability of the learner to select the appropriate equipment and procedure indicates that he/she is able to use science and technology.

UNIT STANDARD ASSESSOR CRITERIA
Assessors should keep the following principles in mind when designing and conducting assessments against this unit standard:

- Focus the assessment activities on gathering evidence in terms of the main outcome expressed in the title to ensure assessment is integrated rather than fragmented. Remember we want to declare the learner competent in terms of the title. Where assessment at title level is unmanageable, then focus assessment around each specific outcome, or groups of specific outcomes.

- Make sure evidence is gathered across the entire range, wherever it applies. Assessment activities should be as close to the real performance as possible, and where simulations or role-plays are used, there should be supporting evidence to show the learner is able to perform in the real situation.

- Do not focus the assessment activities on each assessment criterion. Rather make sure the assessment activities focus on outcomes and are sufficient to enable evidence to be gathered around all the assessment criteria.

- The assessment criteria provide the specifications against which assessment judgements should be made. In most cases, knowledge can be inferred from the quality of the performances, but in other cases, knowledge and understanding will have to be tested through questioning techniques. Where this is required, there will be assessment criteria to specify the standard required.

- The task of the assessor is to gather sufficient evidence, of the prescribed type and quality, as specified in this unit standard, that the learner can achieve the outcomes again and again and again. This means assessors will have to judge how many repeat performances are required before they believe the performance is reproducible.

- All assessments should be conducted in line with the following well documented principles of assessment: appropriateness, fairness, manageability, integration into work or learning, validity, direct, authentic, sufficient, systematic, open and consistent.

UNIT STANDARD NOTES
Specified requirements include legal and site-specific requirements and are contained in one or more of the following documents:

Legal requirements:
- OHS Act and Regulations 85 / 1993
- Mine Health and Safety Act and Regulations 29/1996
- Guideline for mandatory Codes of Practice

Site-specific requirements:
- Managerial instructions
- Codes of Practice
- Company Standards
- Standard Task Procedures
- Health Management Programme
- Risk Assessment Documentation

- Working Guides
- Manufacturers` specifications

QUALIFICATIONS UTILIZING THIS UNIT STANDARD:

	ID	QUALIFICATION TITLE	LEVEL	STATUS	END DATE
Elective	48804	National Certificate: Occupational Safety, Hygiene and Environment	Level 2	Reregistered	2010-08-07

APPENDIX H: UNIT STANDARD FOR NATIONAL CERTIFICATE IN OHS&E

SOUTH AFRICAN QUALIFICATIONS AUTHORITY

REGISTERED QUALIFICATION:

National Certificate: Occupational Safety, Hygiene and Environment

SAQA QUAL ID	**QUALIFICATION TITLE**		
48804	National Certificate: Occupational Safety, Hygiene and Environment		
SGB NAME		**REGISTERING PROVIDER**	
SGB Occupational Health and Safety			
Quality Assuring ETQA			
HW SETA-Health and Welfare Sector Education and Training Authority			
QUALIFICATION TYPE	**FIELD**	**SUBFIELD**	
National Certificate	Field 09 - Health Sciences and Social Services	Preventive Health	
ABET BAND	**MINIMUM CREDITS**	**NQF LEVEL**	**QUAL CLASS**
Undefined	135	Level 2	Regular-Unit Stds Based
REGISTRATION STATUS	**SAQA DECISION NUMBER**	**REGISTRATION START DATE**	**REGISTRATION END DATE**
Reregistered	SAQA 0160/05	2007-08-07	2010-08-07

PURPOSE AND RATIONALE OF THE QUALIFICATION

This qualification enables learners to identify and evaluate occupational safety, hygiene and environmental factors, in occupational environments, which may have a detrimental effect on the health and safety of learners in such environments. Learners credited with this qualification are able to perform essential measurements and functions that promote a culture of health and safety in occupational environments. The qualification is designed to be flexible and accessible.

Learners credited with this qualification are capable of:

- Communicating effectively using visual, mathematic and language skills in the modes of oral and written presentation
- Solving mathematics problems related to finances, patterns, statistics, shape and motion using numbers and number systems
- Describing concepts and principles in science and the natural environment
- Operating personal computers and computer systems
- Collecting, analyzing, organizing and critically evaluating information about occupational hygiene, safety and environmental conditions and elements using science and technology effectively and critically to measure them
- Identifying and solving problems to make responsible decisions regarding workplace hazards and risks
- Ensuring safe, healthy workplace environments and conduct
- Working effectively with others as a member of a team, group, organization or community to attain generic occupational, as well as specialized occupational safety or hygiene or environment operational competence

Rationale:

Learners credited with this qualification are likely to be working in the occupational safety, hygiene and environmental disciplines. For attainment of the Unit Standards, learners are required to integrate practical skills with essential knowledge, and to obtain the qualification they are required to integrate the competencies credited in the Unit Standards that the qualification is based on.

In South Africa and internationally, the social and economic impact of occupational safety, hygiene, health, and environment is great. Direct costs that result from poor workplace safety, hygiene, health, and environments include human and economic costs. Indirect costs are also incurred and can include poor morale, poor productivity, downtime, etc. Improved workplace safety, hygiene, health, and environments could influence the South African economy in direct costs alone to the value of millions of Rands each year. This qualification aims to meet the demand for learners that are able to facilitate a safe, healthy and productive occupational environment.

There is a critical need in the industry to recognize learner competence regarding essential operations associated with a healthy, safe and productive working environment. This qualification is the entry level to a career path in one of the areas of specialization in Occupational Safety, Hygiene and Environment (SHE). It is generic enough to allow maximum mobility within the field of application. Skills, knowledge, values and attitudes (competencies) reflected in the qualification are building blocks towards a level 4 qualification.

LEARNING ASSUMED TO BE IN PLACE AND RECOGNITION OF PRIOR LEARNING
This qualification was designed based on the assumption that learners embarking on learning towards this qualification have already attained the language, communication, and mathematic literacy competencies required at NQF Level 1, including that they are able to:

- Engage in a range of speaking and listening interactions for a variety of purposes
- Explore and use a variety of strategies to learn
- Identify and respond to selected literary texts
- Read and respond to a range of text types
- Write for a variety of different purposes analyse cultural products and processes as representations of shape, space and time
- Collect, analyse, use and communicate numerical data
- Critically analyse how mathematics is used in social, political and economic relations
- Demonstrate an understanding of and use the numbering system
- Describe and represent objects and the environment in terms of shape, space, time and motion
- Describe, represent and interpret mathematic models in different contexts
- Use algebraic notation, conventions and terminology to solve problems
- Use maps to access and communicate information concerning routes, location and direction
- Work with measurement in a variety of contexts
- Work with patterns in various contexts
- Working with numbers in various contexts

Recognition of Prior Learning (RPL):

This qualification can be achieved wholly, or in part, through recognition of prior learning. Evidence can be presented in a variety of forms, including previous international or local qualifications, reports, testimonials, mentoring, functions performed, portfolios, work records and performance records. As such, evidence should be judged according to the general principles of assessment described in the notes to assessors below. Learners who have met the requirements of any Unit Standard that forms part of this qualification may apply for recognition of prior learning to the relevant Education and Training Quality Assurance body (ETQA). The applicant must be assessed against the specific outcomes and with the assessment criteria for the relevant Unit Standards. A qualification will be awarded should a learner demonstrate that the exit level outcomes of the qualification have been attained.

RECOGNISE PREVIOUS LEARNING?
Yes

QUALIFICATION RULES
All Fundamental component Unit Standards are compulsory (52 credits must be attained):
- 20 credits for Communication and Language
- 16 credits for Mathematic Literacy

- 7 credits for Natural Sciences
- 9 credits for Computer Literacy

All Core component Unit Standards are compulsory (70 credits must be attained).

The Elective Component consists of a number of unit standards from which at least 13 credits must be attained.

EXIT LEVEL OUTCOMES

1. Communicate effectively using visual, mathematic and language skills in the modes of oral and written presentation.

2. Solve mathematic problems related to finances, patterns, statistics, shape and motion using numbers and number systems.

3. Describe concepts and principles in science and the natural environment.

4. Operate personal computers and computer systems.

5. Collect, analyze, organize and critically evaluate information about occupational hygiene, safety and environmental conditions and elements using science and technology effectively and critically to measure them. Range: Measurement of mass, pressure, noise levels, air velocity, volume flow rate, illumination levels, environmental thermal conditions, impact of industrial processes on environmental receptors, ventilation, gases etc. are included.

6. Identify and solve problems to make responsible decisions regarding workplace hazards and risks. Range: Risks include sexually transmitted diseases such as HIV/AIDS.

7. Ensure safe, healthy workplace environments and conduct. Range: Qualifying learners are required to take responsibility for their own conduct.

8. Work effectively with others as a member of a team, group, organization or community to attain generic occupational, as well as specialized occupational safety, hygiene, environment OR occupational medicine operational competence.

ASSOCIATED ASSESSMENT CRITERIA

1.
- Information from texts is accessed and used appropriately and effectively for specific contexts
- Oral communication is maintained and adapted according to specific contexts
- Writing is appropriate for defined contexts

2.
- Related problems are solved using patterns and basic mathematic functions
- Life and work related problems are investigated using relevant statistics
- Rational and irrational numbers and number systems are used effectively
- Shape and motion in 2- and 3-dimensional space are describe and represented accurately
- Financial aspects of personal and community life are investigated and monitored effectively for specified contexts

3.
- The concept of science is described correctly
- Fundamental concepts and principles in the natural sciences are described correctly
- Human systems are accurately described
- The relationship between society and the natural environment is accurately described

4.
- Personal computer systems and operating systems are used effectively for specified contexts
- Personal computer systems and operating systems are used correctly
- Use of personal computer systems and operating systems meet security requirements

5.
- Identification and description of occupational hygiene, safety and environmental conditions and elements are accurate
- Relevant principles of measurement are accurately identified and described

- Measurements are accurate
- Measurements selected are appropriate for specified contexts
- Instruments and technologies selected for measurement are appropriate for specified contexts and purposes
- Relevant legal and other context-specific requirements are adhered to

6.
- Occupational safety, hygiene and environment principles are accurately described
- Workplace hazards and risks are accurately identified
- Workplace hazards and risks are addressed according to specified procedures and requirements
- Workplace hazards and risks are recorded according to specified recording procedures
- Workplace hazards and risks are reported according to specified reporting procedures
- Corrective and/or mitigation measures are taken where necessary
- Corrective and/or mitigation measures are appropriate for specified context

7.
- Workplace safety, health and environmental principles and procedures are accurately described
- Workplace safety, health and environmental requirements are adhered to at all times
- Personal protective and monitoring equipment is used correctly and when appropriate

8.
- Workplace safety and health requirements are adhered to
- Principles of safety, hygiene and environment management are adhered to
- Analysis is accurate (Range: Analysis of, for example, dust samples, life sustainability of refuge chambers, etc. is included)
- Inspections meet specified requirements (Range: Inspections include, for example, inspection of percussion rock drills, and safety inspections)
- Sampling and measurements are accurate and meet specified requirements (Range: Sampling and measurement of, for example, water content, temperature, radioactive contamination, radiation, cooling power, low air velocities, air, water and barometric pressure, thermal conditions, personal equivalent noise exposure levels, environmental pollution, etc.)
- Primary emergency care requirements are met (Range: Dealing with wounds, fractures, thermal conditions, reporting to the compensation commissioner, etc.)

Integrated Assessment:

Learners may be credited for individual unit standards when they meet the requirements of each unit standard. For award of the qualification, a learner must achieve all core and fundamental Unit Standards, and at least 13 credits from any of the elective Unit Standards. The assessment criteria in the Unit Standards are performance-based, assessing applied competence rather than only knowledge, or skills. In addition, learners must demonstrate that they can achieve the outcomes in an integrated manner, dealing effectively with different and random demands related to the environmental conditions in occupational contexts, to qualify. Evidence is required that the learner is able to achieve the exit level outcomes of the qualification as a whole and thus its purpose, at the time of the award of the qualification. Workplace experience can be recognised when assessing towards this qualification.

INTERNATIONAL COMPARABILITY

This qualification and component Unit Standards for this qualification have been compared with other countries. The qualification does not exist at the equivalent level on frameworks in New Zealand, United Kingdom, and Australia. However, the design of the qualification addresses equivalent areas of competence.

On the Australian framework, occupational health, safety and environment qualifications fall within the Vocational Education and Training sector, which recognises skills and knowledge that meet nationally endorsed industry/enterprise competency standards as agreed for those qualifications by the relevant industry, enterprise, community or professional group. The available qualifications also include literacy and numeracy, communication, working in teams (critical cross field outcome on the South African NQF), workplace technology, and industry specific competencies. Various programs are available, including a Certificate III in Occupational Health and Safety, Certificate IV in Auditing Occupational Health and Safety Systems, Certificate IV in Occupational Health and Safety, and a Diploma of Occupational Health and Safety. Certificate III is year 12, or equivalent to the South African NQF Level 4.

In the United Kingdom, no equivalent for the South African NQF Level 2 qualification exists. A Foundation certificate in Health and safety in a workplace is available, within the Hospitality sector. In addition, National Vocational Qualifications exist for Security, Safety and Loss Prevention at Level 2, Occupational Health and Safety at Level 3 (Grade 12 or NQF Level 4 equivalent in South Africa), Occupational Health and Safety Practice at Levels 4 and 5 and Health and Safety Regulation at Level 5. Other than these, health, safety and environmental issues are integrated within most other relevant qualifications, such as general science (equivalent to NQF Level 1 in South Africa), design, and engineering. In Scotland, two Vocational qualifications are provided, namely, Occupational Health and Safety Practice at Level 3, and Occupational Health and Safety Practice at Level 4.

The New Zealand NQF places occupational health and safety within the fields of Health, Manufacturing (Dairy Workplace Health and Safety) and Planning and Construction (Construction Health and Safety and Injury Prevention). The South African equivalent is in the field of Health, specifically Occupational Health and Safety. The South African NQF Level 4 is the equivalent of the New Zealand NQF Level 3. Two qualifications are registered in the field of Health, on the New Zealand NQF, namely, a National Certificate in Occupational Health and Safety (Co-ordination) (Level 4), and a National Certificate in Occupational Health and Safety (Workplace Safety) (Level 3).

Unit standards on the New Zealand NQF are all at a higher level than this qualification, and include the following:

- Protect health and safety in a workplace (Level 1, Credits 1)
- Assist in evaluating occupational health and safety standards and practice (Level 4, Credits 15)
- Assist in hazard identification and control for occupational health and safety practice (Level 4, Credits 10)
- Demonstrate knowledge of health and safety management requirements for contractors working on site (Level 4, Credits 8)
- Explain the establishment and operation of a workplace health and safety committee (Level 4, Credits 5)
- Explain the requirements of the health and safety in employment act (HSE) 1992 (Level 4, Credits 2)
- Maintain standards of practice in an occupational health and safety practice (Level 5, Credits 5)
- Develop and implement workplace occupational health and safety policy and standards (Level 5, Credits 10)
- Develop systems for occupational health and safety management practice (Level 6, Credits 20)
- Evaluate occupational health and safety standards and practice (Level 6, Credits 30)
- Facilitate hazard management in an occupational health and safety practice (Level 6, Credits 30)
- Plan and evaluate programmes to promote occupational health and safety practice (Level 6, Credits 20)
- Implement workplace health and safety management requirements (Level 4, Credits 25)
- Manage workplace management health and safety (Level 5, Credits 10)

ARTICULATION OPTIONS
This qualification can provide access to learners to progress to higher-level qualifications in the discipline of Occupational Safety, Hygiene and Environment, and in various industrial sectors and related sub-fields. Most qualifications on the NQF require competence regarding this discipline, and thus provide an access point to, for example qualifications in the Physical Planning and Construction field, the Manufacturing, Engineering and Technology field, the Business, Commerce and Management Field, etc.

The qualification, through the fundamental component for communication and mathematic literacy, articulates horizontally with all NQF registered qualifications at NQF Level 2, and vertically up and down with NQF Levels 1 and 3. In addition, Fundamental Unit Standards relating to Natural Sciences and Computer Literacy form part of many other NQF qualifications.

MODERATION OPTIONS
Moderation of assessment and accreditation of providers shall be at the discretion of a relevant ETQA as long as it complies with the SAQA requirements. The ETQA is responsible for moderation of learner achievements of learners who meet the requirements of this qualification. Particular moderation and accreditation requirements are:

- Any institution offering learning that will enable the achievement of this qualification must be accredited as a provider with the relevant ETQA. Providers offering learning towards achievement of any of the Unit Standards that make up this qualification must also be accredited through the relevant ETQA accredited by SAQA.

- The ETQA will oversee assessment and moderation of assessment according to their policies and guidelines for assessment and moderation, or in terms of agreements reached around assessment and moderation between the relevant ETQA and other ETQAs and in terms of the moderation guideline detailed here.

- Moderation must include both internal and external moderation of assessments for the qualification, unless the relevant ETQA policies specify otherwise. Moderation should also encompass achievement of the competence described in Unit Standards as well as the integrated competence described in the qualification.

- Internal moderation of assessment must take place at the point of assessment with external moderation provided by a relevant ETQA according to the moderation guidelines and the agreed ETQA procedures.

- Anyone wishing to be assessed against this qualification may apply to be assessed by any assessment agency, assessor or provider institution that is accredited by the relevant ETQA.

CRITERIA FOR THE REGISTRATION OF ASSESSORS

Assessment of learner achievements takes place at providers accredited by the relevant ETQA (RSA, 1998b) for the provision of programmes that result in the outcomes specified for the National Certificate in Occupational Safety, Hygiene and Environment (NQF Level 2). Anyone assessing a learner or moderating the assessment of a learner against this qualification must be registered as an assessor with the ETQA. Assessors registered with the relevant ETQA must carry out the assessment of learners for the qualification and any of the Unit Standards that make up this qualification.

To register as an assessor, the following are required:

- Detailed documentary proof of relevant qualification/s, practical training completed, and experience gained (a Portfolio of Evidence)

- NQF recognised assessor credits.

Assessors should keep the following general principles in mind when designing and conducting assessments:

- Focus the initial assessment activities on gathering evidence in terms of the main outcomes expressed in the titles of the Unit Standards to ensure assessment is integrated rather than fragmented. Remember that the learner needs to be declared competent in terms of the qualification purpose and exit level outcomes.

- Where assessment across Unit Standard titles or at Unit Standard title level is unmanageable, then focus assessment around each specific outcome, or groups of specific outcomes. Take special note of the need for integrated assessment.

- Make sure evidence is gathered across the entire range, wherever it applies.

In particular, assessors should assess that the learner demonstrates an ability to consider a range of options by:

- Measuring the quality of the observed practical performance as well as the theory and underpinning knowledge.

- Using methods that are varied to allow the learner to display thinking and decision making in the demonstration of practical performance.

- Maintaining a balance between practical performance and theoretical assessment methods to ensure each is measured in accordance with the level of the qualification.

- Taking into account that the relationship between practical and theoretical components is not fixed, but varies according to the type and level of qualification.

All assessments should be conducted in line with the following well-documented principles:

- Appropriate: The method of assessment is suited to the performance being assessed.

- Fair: The method of assessment does not present any barriers to achievements, which are not related to the evidence.

- Manage: The methods used make for easily arranged cost-effective assessments that do not unduly interfere with learning.

- Integrate into work or learning: Evidence collection is integrated into the work or learning process where this is appropriate and feasible.

- Valid: The assessment focuses on the requirements laid down in the standards; i.e. the assessment is fit for purpose.

- Direct: The activities in the assessment mirror the conditions of actual performance as close as possible.

- Authentic: The assessor is satisfied that the work being assessed is attributable to the learner being assessed.

- Sufficient: The evidence collected establishes that all criteria have been met and that performance to the required Standard can be repeated consistently.

- Systematic: Planning and recording is sufficiently rigorous to ensure that assessment is fair.

- Open: Learners can contribute to the planning and accumulation of evidence. Learners for assessment understand the assessment process and the criteria that apply.

- Consistent: The same assessor would make the same judgement again in similar circumstances. The judgement made is similar than the judgement that would be made by other assessors.

NOTES
N/A

UNIT STANDARDS:

	ID	UNIT STANDARD TITLE	LEVEL	CREDITS
Core	110075	Apply basic fire fighting techniques	Level 1	3
Core	14656	Demonstrate an understanding of sexuality and sexually transmitted infections including HIV/AIDS	Level 1	5
Core	116527	Demonstrate knowledge pertaining to basic health and safety principles in and around a workplace	Level 1	2
Core	115096	Issue and retrieve personal monitoring equipment	Level 1	1
Core	7489	Show, explain, discuss and analyse the relationship between society and natural environment	Level 1	4
Core	115101	Address workplace hazards and risks	Level 2	4
Core	116520	Apply safety, health and environmental principles and procedures in a workplace	Level 2	2
Core	115087	Conduct a preliminary incident investigation into workplace health, safety and environmental incidents	Level 2	2
Core	116518	Conduct safety and health representation activities	Level 2	3
Core	116533	Demonstrate basic knowledge and understanding of emergency preparedness and response	Level 2	2
Core	115105	Determine wet and dry bulb temperature by means of a whirling hygrometer and take appropriate action	Level 2	2
Core	115102	Identify, locate and record evironmental elements using a geographical positioning system (GPS)	Level 2	2
Core	115092	Measure and record the concentration of flammable and noxious gases and vapours and take appropriate action	Level 2	2
Core	115091	Monitor compliance to safety, health and environmental requirements in a workplace	Level 2	2
Core	119355	Participate in the development, implementation and evaluation of a safety, health and environmental management programme in the workplace	Level 2	2
Core	115097	Participate in the establishment, implementation and monitoring of a health and safety agreement	Level 2	2
Core	115099	Plan sampling and analysis	Level 2	2
Core	116534	Carry out basic first aid treatment in the workplace	Level 3	2
Core	115093	Control workplace hazardous substances	Level 3	4
Core	116523	Demonstrate knowledge of basic occupational hygiene principles	Level 3	2

Core	115109	Grade the potential of specified industrial processes to impact on environmental receptors	Level 3	5
Core	116524	Measure environmental factors and take appropriate action	Level 3	15
Fundamental	14110	Demonstrate an understanding of fundamental concepts and principles in the natural sciences	Level 1	5
Fundamental	7507	Demonstrate an understanding of the concept of science	Level 1	2
Fundamental	8963	Access and use information from texts	Level 2	5
Fundamental	9009	Apply basic knowledge of statistics and probability to influence the use of data and procedures in order to investigate life related problems	Level 2	3
Fundamental	7480	Demonstrate understanding of rational and irrational numbers and number systems	Level 2	3
Fundamental	9008	Identify, describe, compare, classify, explore shape and motion in 2-and 3-dimensional shapes in different contexts	Level 2	3
Fundamental	8962	Maintain and adapt oral communication	Level 2	5
Fundamental	7547	Operate a personal computer system	Level 2	6
Fundamental	8967	Use language and communication in occupational learning programmes	Level 2	5
Fundamental	7469	Use mathematics to investigate and monitor the financial aspects of personal and community life	Level 2	2
Fundamental	7548	Use personal computer operating system	Level 2	3
Fundamental	9007	Work with a range of patterns and functions and solve problems	Level 2	5
Fundamental	8964	Write for a defined context	Level 2	5
Elective	116509	Apply primary emergency life support	Level 1	2
Elective	116511	Carry out basic first aid treatment in the workplace	Level 1	1
Elective	119568	Demonstrate basic occupational health and knowledge pertaining to the principles of handling of materials in a workplace	Level 1	1
Elective	116508	Demonstrate basic understanding of the procedure for compensation claims submissions for occupational injuries and diseases	Level 1	2
Elective	116516	Apply stone dust to inertise coal dust	Level 2	2
Elective	115107	Collect water sample for analysis	Level 2	2
Elective	116503	Completion of Compensation Commissioner documentation for Occupational Injuries and Diseases	Level 2	3
Elective	116517	Conduct routine inspections on percussion rock drills	Level 2	2
Elective	116513	Examine refuge chambers to ensure they are life sustainable	Level 2	1
Elective	116507	Explain the functional aspects of the human anatomy in the use of primary emergency care terminology	Level 2	1
Elective	115090	Install explosion barriers to control the propagation of coal dust explosions	Level 2	2
Elective	115094	Measure and record pressures and take appropriate action	Level 2	2
Elective	115089	Measure virgin rock temperature	Level 2	2
Elective	116505	Perform a vision-screening test in the working place	Level 2	2
Elective	115103	Sample and evaluate a mixture of coal dust and stone dust	Level 2	3

Elective	116498	Analyse absenteeism related to occupational health/medical related conditions in the work place	Level 3	4
Elective	116501	Demonstrate the interpretation of vital signs when providing primary emergency care or first aid	Level 3	1
Elective	116515	Determine the amount of rock dust and particulate matter in water	Level 3	4
Elective	116499	Perform vital signs in the working place	Level 3	6
Elective	116496	Provide primary emergency care for bleeding and wounds	Level 3	1
Elective	116500	Provide primary emergency life support for fractures and dislocations	Level 3	1
Elective	116497	Provision of primary emergency care intervention for shock, unconsciousness and fainting in the working place	Level 3	1

LEARNING PROGRAMMES RECORDED AGAINST THIS QUALIFICATION:
NONE

APPENDIX I: MHSA ACT REGULATIONS

17.2 The employer must engage the part-time or full services of a competent person to be in charge of surveying, mapping and mine plans at the mine, and if the services of more that one competent person are engaged, ensure that their functions do not overlap.

17.5(a) working which are being advanced;

17.5(e) safety pillars that are being, or have been, removed.

17.9 The employer must take reasonable measures to ensure that the relevant survey records and plans resulting from conditions described in regulation 17.5[a] and 17.5[e] are updated by the competent person referred to in regulation 17.2 at intervals not exceeding three months.

APPENDIX J: MINE HEALTH AND SAFETY ACT, 1996 CHAPTER 4, SECTION 10 - EMPLOYER TO PROVIDE HEALTH AND SAFETY TRAINING

1) As far as reasonably practicable, every employer must--

a) provide employees with any information, instruction, training or supervision that is necessary to enable them to perform their work safely and without risk to health; and

b) ensure that every employee becomes familiar with work-related hazards and risks and the measures that must be taken to eliminate, control and minimize those hazards and risks. *(Employees must not be made to pay for health and safety training. See section 24.)*

2) As far as reasonably practicable, every employer must ensure that every employee is properly trained--

a) to deal with every risk to the employee's health or safety that--

   i) is associated with any work that the employee has to perform, and

   ii) has been recorded in terms of section 11;

b) in the measures necessary to eliminate, control and minimize those risks to health or safety;

c) in the procedures to be followed to perform that employee's work; and

d) in relevant emergency procedures.

3) In respect of every employee, the provisions of subsection (2) must be complied with--

a) before that employee first starts work;

b) at intervals determined by the employer after consulting the health and safety committee;

c) before significant changes are introduced to procedures, mining and ventilation layouts, mining methods, plant or equipment and material; and

d) before significant changes are made to the nature of that employee's occupation or work.

APPENDIX K: LAUNCH OF AWARENESS TRAINING PROGRAMME FOR ANGLO COAL AT CSIR KLOPPERSBOS FACILITY

A mine explosion and fire awareness training programme developed specifically for Anglo Coal underground personnel was re-launched at the CSIRs Kloppersbos facility yesterday. The event, which included a number of explosion demonstrations, was attended by a number of Anglo Coal representatives, as well as officials from the Department of Minerals and Energy (DME).

Originally initiated in 2002, the programme has been updated and modified to include fire awareness training (in addition to the training on methane and coal dust explosions offered in the original course). The programme will kick off in July 2006 with weekly training sessions, limited to 40 individuals per session.

According to Karel van Dyk, Manager: Explosion Testing and Fire Management at CSIR Knowledge Services, the purpose of the programme is to increase awareness of the risk presented by fire and explosions in the underground environment. In particular, the programme aims to familiarize Anglo Coal personnel with a number of key issues, including:

- the importance of mine ventilation
- strategies for preventing coal mine explosions
- possible ignition sources for fires and explosions
- how different explosion barriers operate

During his welcoming address, Van Dyk pointed out that the course was an important part of the CSIRs contribution to an improved safety record in the coal mining industry. He emphasized that Anglo Coal had pioneered the idea of a tailor-made course dedicated to the training needs of their underground personnel. He also acknowledged the DMEs support for the programme.

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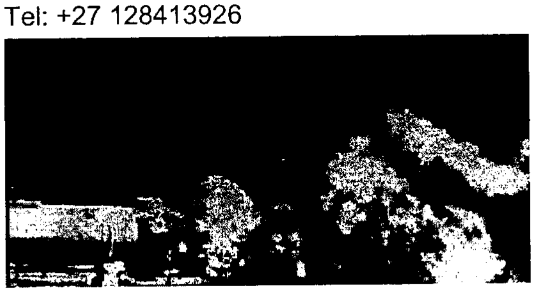
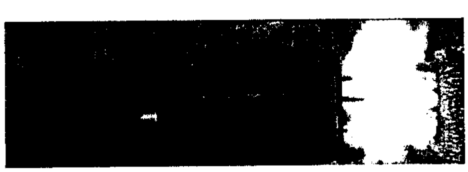
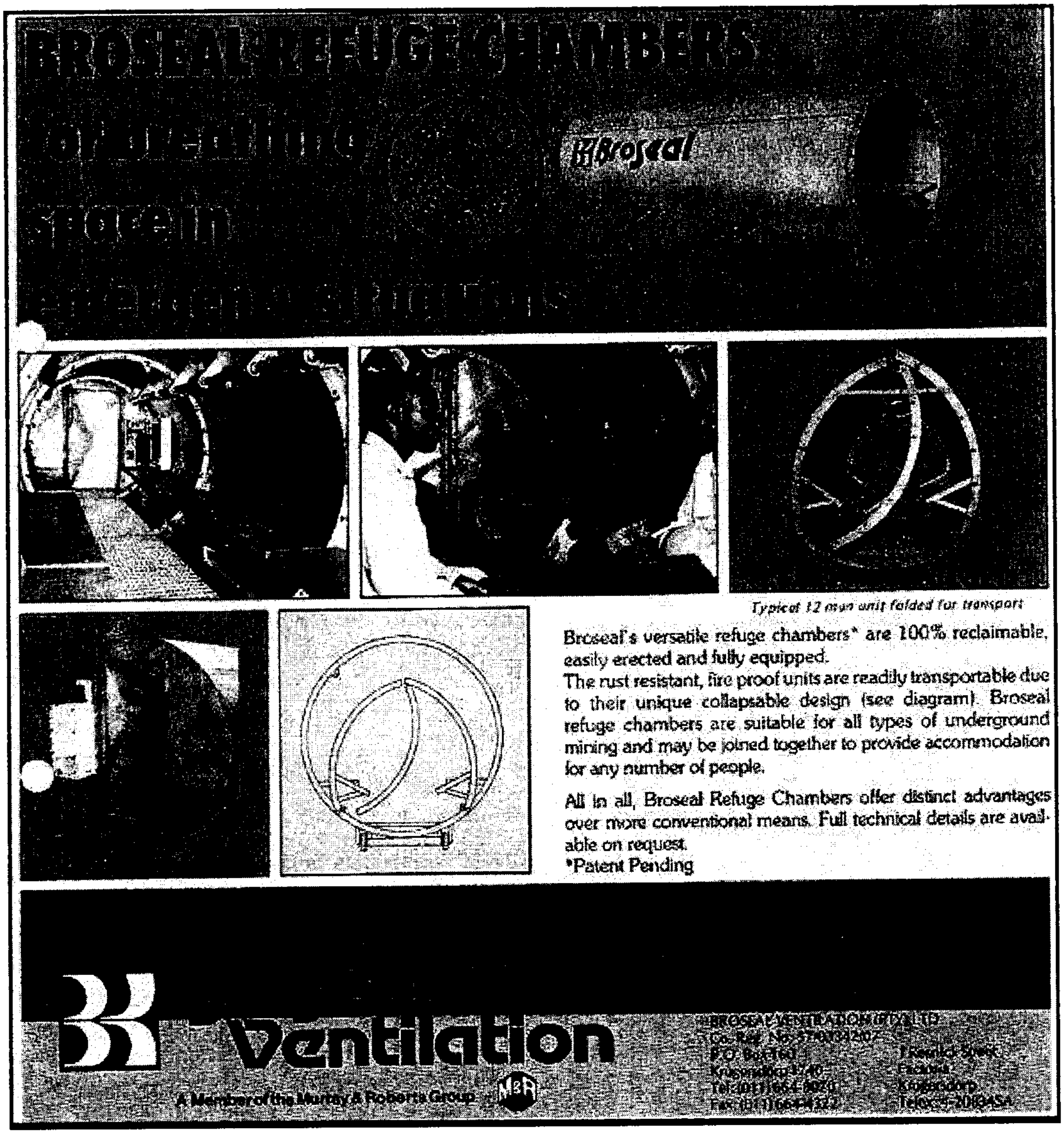
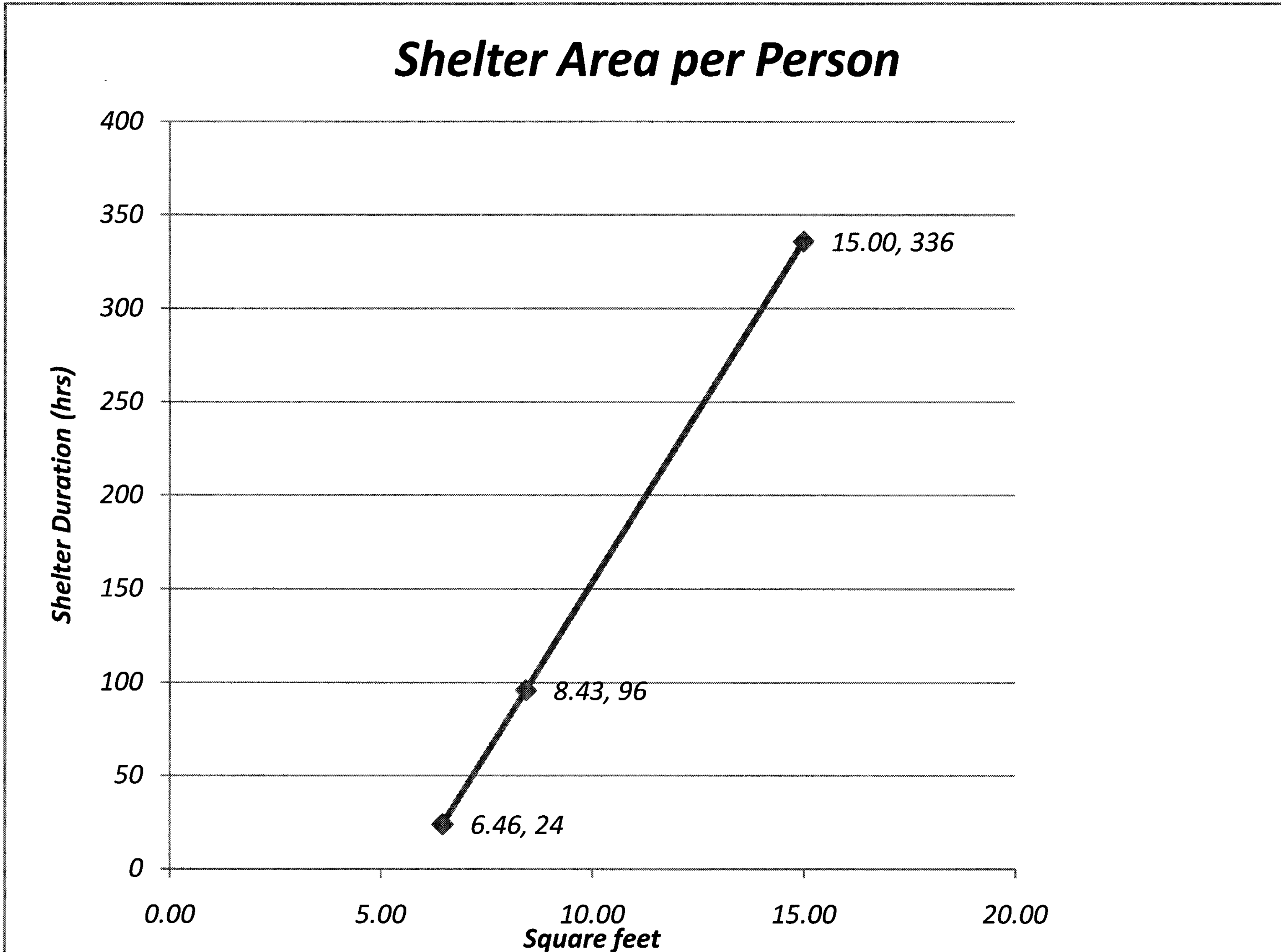




APPENDIX L: EXAMPLE OF EARLY COLLAPSIBLE REFUGE CHAMBER





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			Volume & Area Less Airlock and Scrubber						Volume & Area Less Airlock, Scrubber, and Tube Structure					
			Volume/Area per Man @ Rated Occupancy		Maximum Occupancy Per Proposed Rule Spec		Derated		Volume/Area per Man @ Rated Occupancy		Maximum Occupancy Per Proposed Rule Spec		Derated	
FAB MODEL	Rated Occupancy	Height	Cu.Ft./Man	Sq.Ft./Man	@60 cu.ft/Man	@15 sq.ft./Man	Occupancy	Derated %	Cu.Ft./Man	Sq.Ft./Man	@60 cu.ft/Man	@15 sq.ft./Man	Occupancy	Derated %
M1616	16	3	51.7	16.8	13.8	17.9	13	18.8%	38.3	13.3	10.2	14.2	10	37.5%
	16	3.5	30.9	8.4	8.2	9.0	8	50.0%	20.2	6.0	5.4	6.4	5	68.8%
	16	5.5	54.2	9.4	14.4	10.0	10	37.5%	38.3	6.9	10.2	7.4	7	56.3%
M2620	20	3	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
	20	3.5	34.9	9.4	11.6	12.5	11	45.0%	24.0	7.1	8.0	9.5	8	60.0%
	20	5.5	49.7	8.4	16.6	11.2	11	45.0%	36.1	6.3	12.0	8.4	8	60.0%
M2624	24	3.5	43.7	12.0	17.5	19.2	17	29.2%	32.2	9.6	12.9	15.3	12	50.0%
	24	5.5	60.0	10.4	24.0	16.6	16	33.3%	45.7	8.3	18.3	13.2	13	45.8%
M2626	26	3.5	40.3	11.1	17.5	19.2	17	34.6%	29.8	8.8	12.9	15.3	12	53.8%
	26	5.5	55.4	9.6	24.0	16.6	16	38.5%	42.1	7.6	18.3	13.2	13	50.0%
M2630&3630	30	3.5	42.3	11.6	21.2	23.3	21	30.0%	32.1	9.4	16.0	18.8	16	46.7%
	30	5.5	57.9	10.0	28.9	20.0	20	33.3%	44.6	8.1	22.3	16.2	16	46.7%
M3636	35	3.5	46.6	12.9	27.2	30.1	27	22.9%	35.7	10.6	20.8	24.8	20	42.9%
	35	5.5	64.4	11.3	37.6	26.3	26	25.7%	51.0	9.3	29.8	21.6	21	40.0%
M3636	36	3.5	45.3	12.6	27.2	30.1	27	25.0%	34.7	10.3	20.8	24.8	20	44.4%
	36	5.5	62.6	11.0	37.6	26.3	26	27.8%	49.6	9.0	29.8	21.6	21	41.7%
MC3636	35	3.5	46.7	13.0	27.3	30.2	27	22.9%	36.1	10.7	21.1	24.9	21	40.0%
	35	5.5	64.4	11.3	37.6	26.3	26	25.7%	50.5	9.3	29.5	21.6	21	40.0%
MC3636	36	3.5	45.4	12.6	27.3	30.2	27	25.0%	35.1	10.4	21.1	24.9	21	41.7%
	36	5.5	62.6	11.0	37.6	26.3	26	27.8%	49.1	9.0	29.5	21.6	21	41.7%
							Max	50.0%					Max	68.8%
							Min	18.8%					Min	37.5%

Based on Data provided by Strata Products 7/21/08

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