Summary Information on Refuge Chamber Use and Moving in Underground Coal Mines

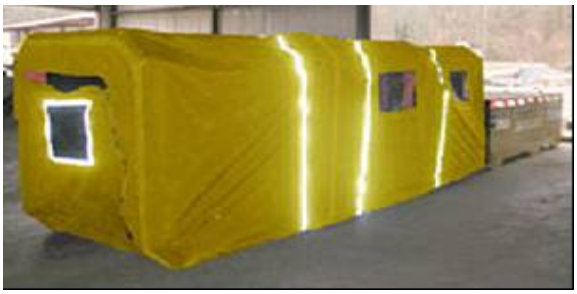
Introduction

This report provides information about the practical side of moving and locating refuge chambers on active working sections in underground coal mines. It covers information on both refuge chambers (rigid/steel and inflatable) and safe havens (an alternative) that are being considered by mine operators and provides some insight into the reasons, as well as some challenges, associated with each choice. This report also provides information on manpower requirements, personnel responsibilities, safety concerns, and special considerations or modifications that will be required by mine operators to accommodate their choice of refuge alternative selection.

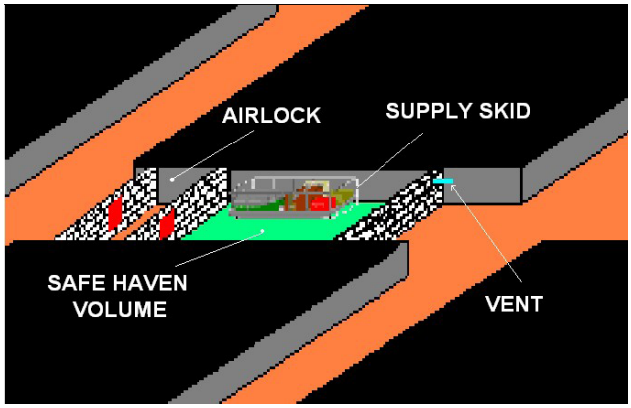
The summary information in this report represents 105 mines from 21 different mining companies and 15 out of the 17 states with underground bituminous coal mines. These states include Alabama, Colorado, Kentucky, Illinois, Indiana, Maryland, Montana, New Mexico, Ohio, Oklahoma, Pennsylvania, Utah, Virginia, West Virginia, and Wyoming. Review of the information indicates that a "one size fits all" approach does not apply when it comes to refuge alternative selection and use. Among mining companies, a large variability exists in both choice of design and operational considerations. These variations are a result of a wide-range of factors including mining methods (longwall or room and pillar), number of miners on each working section, mining height, mine design and pillar size, mine power system (electrical, diesel, battery), underground mining conditions (environmental), regulatory considerations both state (West Virginia) and federal, economic considerations and detailed information on testing, technology, and training needs which is still being developed.

Most mine operators, except for those in West Virginia, have two choices of refuge alternatives for each working section: refuge chambers (rigid steel or inflatable) or safe havens. Regulators from West Virginia are not currently approving the use of safe havens on working sections and therefore mine operators in this state must use refuge chambers. Both kinds of refuge chambers are available in a variety of capacities with varying heights, widths, and lengths.

Steel Chambers, made of a rigid shell, remain the same in size, shape, and geometry even when deployed (see picture at right). The inflatable chambers increase in size when deployed as seen in the picture below (left) and the associated tent structure can extend as far as 24 feet. For this unit, all the materials needed for the deployment are housed inside the rigid steel housing (below right).



Safe Havens are built out of brattice, block, man doors, and other barricade materials. A safe haven, as seen below, involves a block stopping (previously built) with a vent, an airlock (two block stoppings with doors) and the use of a supply skid thereby creating a safe haven or zone. The breathable air systems needed for the safe havens are supplied by either compressed air cylinders located on the supply skid, vertical boreholes drilled from the surface into each safe haven area, or compressed air lines, which are protected against explosive forces, and typically are located along the track or belt line.



Moving and Locating Refuge Alternatives Underground

Refuge alternatives are typically moved from outside of the mine to the working section by a mine scoop (diesel or battery-powered) or by track haulage on a dolly or mine car. The mine scoop is also used to move the refuge alternative around the active working section. Most refuge chambers and safe haven breathable air products are manufactured as skid-mounted assemblies and should fit into the scoop bucket. Mine operators have also requested that hydraulic jacks be attached to the refuge chambers to raise the chamber so that a scoop bucket can get underneath to aid in the moving process. They also mentioned additional hardening of the framework (reinforcing steel) to prevent damage during movement and the installation of wheels for easier movement. Larger and longer chambers will be a greater challenge to move underground, especially for mines with lower seam heights, smaller entry widths, and difficult environmental conditions. One low seam mine, utilizing a 21-ft long steel chamber, has changed their pillar design plan to incorporate angled crosscuts for better maneuverability. Such changes must also address roof control and ventilation concerns.

The new locations for the refuge alternatives must be prepared beforehand by cleaning, pumping, and/or adding additional roof/rib support (if needed). Some operators will hang signs, use lighting (e.g., strobe lights), or provide some other method to help miners find the new locations in the case of an emergency. Barricades and tape may also be used to prevent collisions between machinery and the refuge alternative selected. The new location must also be updated on the mine map and inspected regularly.

In every state except West Virginia, the refuge alternatives must be maintained within 2000 feet of the working face. West Virginia regulations require refuge alternatives to be placed within 1000 feet of the working face. Therefore, the refuge alternatives in West Virginia will have to be moved twice as often as those used in other states. The time between moving a refuge alternative from one place to the next depends on the rate of mining advance which is a function of a variety of factors including mining height, number of entries, mining method, etc.

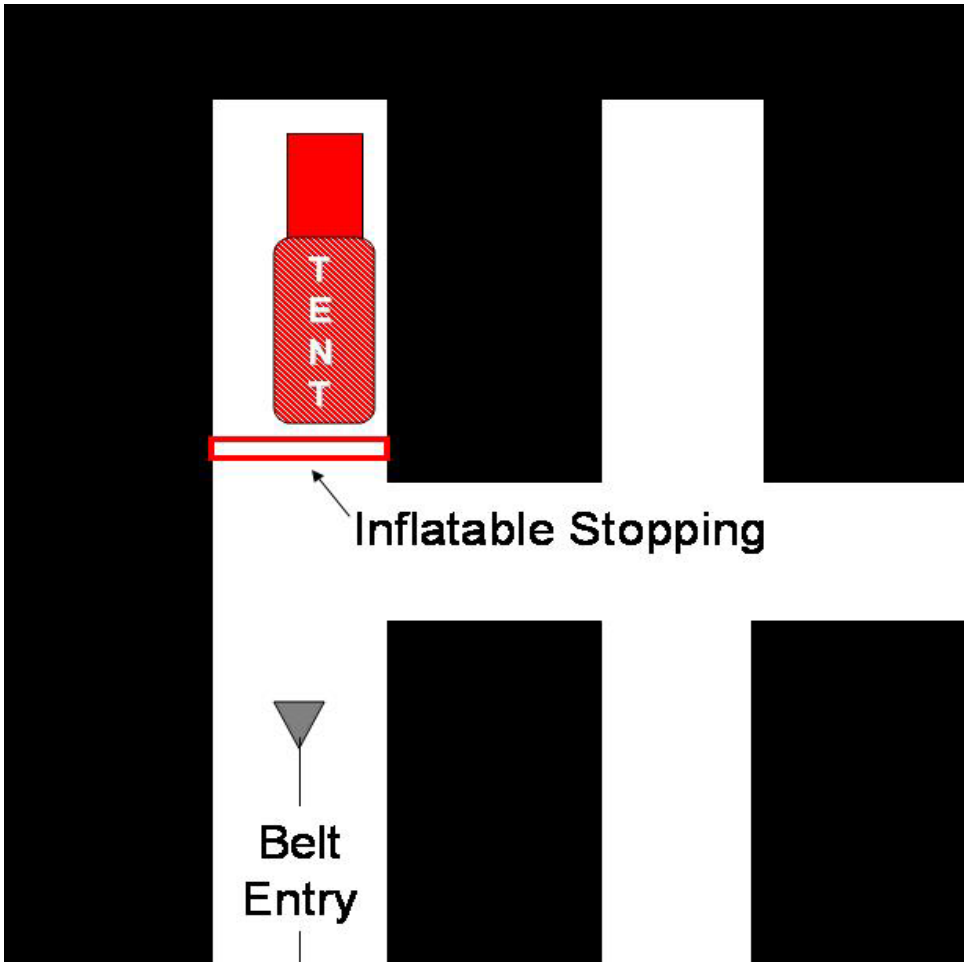
Safe havens will be moved once every 1 or 2 months and are typically designed to be constructed in a crosscut. They do not have to be built at every new location, but the materials, supply skid, and breathable air supply must be present. Mine operators have the option to either move the safe haven materials (on a skid) forward, which may better preserve the building materials, or rebuild the safe havens at the new location. The latter option would allow for more rapid deployment in an emergency situation. Most of the safe havens will be located in a crosscut adjacent to a primary escapeway. The manpower needed to move and/or rebuilt a safe haven ranges from 1 to 2 miners over 1 to 2, 8-hr shifts, not including the time to drill air holes if vertical boreholes are used.

Refuge chambers have much more variability in the time between moves and the location on the section. A small number of mines, more typically at longwall mines, plan to move the chambers along with the power center as part of the regular mining sequence. This can occur between 3 times per week up to twice a month. However, the majority of mine operators plan to move the chambers only when necessary (in accordance to the regulations) which happens between twice a month up to once every 3 months. The manpower needed for each move ranges from 1 to 3 miners over 1 to 4 hours.

Moving a refuge chamber with a power center (typically every 180 to 250 feet) ensures that the chambers will be located as mandated by law because they will be moved much more regularly than the statutes require. However, the frequent handling and moving of the refuge chambers may increase the risk of damage to the chamber and injury to the miners. Moving a refuge chamber with a power center move will also keep the refuge chamber as close as a few hundred feet from the working face. This refuge chamber relocation scenario causes concern for some mine operators because, if an explosion occurs at the face, the refuge chambers may get destroyed because of the close proximity to the explosion.

Refuge chambers will be located on the section either at the end of the track (as part of the power center), in a crosscut, or in the primary or secondary escapeway entry. Most mine operators have chosen to locate the chamber in a crosscut (adjacent to the primary or secondary escapeway) to provide a higher degree of protection from the forces of an explosion. For inflatable chambers, mines must ensure that enough space is provided around the chamber to allow for full deployment. This provides a challenge for mines with short pillar widths and a small number of entries.

Only one mine operator mentioned plans to deploy the refuge chamber in a location other than where it will be stored on the section (in a crosscut). When an emergency occurs, a mine scoop will move the refuge chamber (inflatable) into the face area of the belt entry. Once in place, miners will install an inflatable stopping across the width of the entry as shown below. In this manner, miners can utilize the available oxygen in the volume of air behind the inflatable stopping before deploying the refuge chamber. They will also have an opportunity to communicate with the surface by striking roof bolts. This opportunity is lost once the miners enter the refuge chamber.



Refuge Alternative Inventory Summary

A summary table follows with information from the coal companies inventoried (each representing one or more coal mines) about the choice of refuge alternative, the capacity (maximum number of persons), the reasons for selection, and the primary concerns and challenges associated with each choice. This table also contains information about the kind of mining method for each company (LW = longwall, R&P = room and pillar). Finally, this table is divided into three categories for each mining company related to mining height: 1) coal companies that operate mines with mining heights greater than 60 inches, 2) coal companies that operate mines with mining heights less than 60 inches, and

3) coal companies that operate mines with both mining heights greater than and less than 60 inches.

The results from this table regarding the selection of refuge alternative, the average capacity, and reasons for selection are the following:

- 5 out of 21 companies or 24% (3 LW and 2 R&P) selected steel chambers (average capacity = 20) because of their protection against secondary explosions and the physical integrity of the chamber when moving. Other reasons, deemed not as significant included the ease of underground training, and a preferred carbon dioxide scrubbing system.

- 13 out of 21 companies or 62% (1 LW, 8 R&P, 4 LW and R&P) selected inflatable chambers (average capacity = 26) because of their maneuverability (size), physical integrity when moving, and capacity. Other factors, deemed not as significant were cost, rapid deployment, a preferred carbon dioxide scrubbing system, physical integrity of the chamber during an initial explosion, and insufficient information on refuge chambers.

- 3 out of 21 companies or 14% (1 LW, 1 R&P, 1 LW and R&P) selected safe havens (average capacity = 21). One mine has chosen to build the safe havens at each location and supply the breathable air by compressed air cylinder assemblies, and two mines have chosen to not build the safe havens at each location, but make available all the necessary materials and breathable air supplies (one mine will drill vertical air holes and the other will utilize compressed air cylinder assemblies). The main reasons for selection were cost, insufficient information on refuge chambers and maneuverability. Other factors were a preferred carbon dioxide scrubbing system and capacity.

There were several primary concerns and challenges that were common to the majority of the mining companies inventoried, regardless of refuge alternative selection, mining height, or mining method. The two most common responses were the lack of expertise for training and inspection and potential damage to the chambers or materials when they are being moved. Below is the complete list of concerns and challenges (in order of importance) as well as the percent of mining companies inventoried that shared the same concern.

1. Lack of Expertise for Training and Inspection (76%) - Mining companies are concerned that they lack the expertise to train miners on how and when to properly use their refuge alternative selection and how to ensure they are properly maintained. They are also concerned that regulatory agencies lack the expertise to properly inspect the units. For the inflatable chambers and safe havens, hands-on training will be difficult, if not impossible, because the units are kept underground and cannot be deployed until there is an emergency. Hands-on training will be easier on a steel chamber, but the breathable air systems and supplies can not be used during the training.

2. Damage from Moving (76%) - The underground mining environment is inherently rough and characterized by large and heavy equipment that is operated in fairly confined spaces. It is very easy for equipment to get damaged when being moved from one place to another. Refuge chambers are typically large in size and weight (especially steel chambers) and thus create an even bigger challenge. Because the refuge chambers are considered costly, mining companies are concerned that they will get damaged as they are being moved. One company plans to train only a few miners on how to effectively and safely move these chambers without damage. These miners, equipped with this specialized training, will then be specifically assigned to each refuge chamber move.

3. Environmental Conditions Underground (52%) - A variety of environmental conditions exist that could cause damage to the refuge alternative equipment or require additional efforts to ensure that the units are maintained without damage and in a useable condition. A few mine operators, that anticipate poor roof conditions, plan to build structures above the refuge chambers to provide additional protection from falling rocks and coal from the mine roof and rib. They also plan to install screen on the roof and ribs and other supplemental support, as needed. To minimize water problems, some mines plan to build a ramp and an elevated pad on which to place the refuge chamber. Other environmental concerns are weak mine floors (floor heave) and high ambient temperatures.

4. Increased Risk of Injury from Moving (48%) - As mentioned above, the equipment for refuge chamber alternatives is large, bulky and heavy. This, coupled with using equipment to move them that is also large and fast-moving, has mine operators concerned that there may be an increase in the number of "struck-by or caught-between" injuries.

5. Poor Decisions in Escape versus Rescue (43%) - Mine operators are concerned that the refuge chambers may provide a false sense of security to miners. Faced with an emergency situation, miners may choose to utilize the refuge chamber when escaping from the mine would be the better alternative.

6. Storage of Pressurized O_2 Cylinders (38%) - As mentioned above, a concern exists that damage may occur to the chambers as they are being moved. Because the compressed breathable air cylinders are stored inside these chambers, they may also get damaged. This damage in addition to the potential exposure to a mine fire could create an explosion hazard.

7. Changing Legislations / Regulations (33%) - Mine operators have expressed concerns that compliance to the MINER Act has been demanding and often difficult, especially in the case of refuge chambers because of the high cost of equipment. The lack of approved and tested technology is also a concern. They are also concerned that the laws and regulations may change again soon and that some mine operators (especially small operators) may not be able to continue to operate under more stringent regulations.

8. Longevity of Chamber and Contents (33%) - Mine operators are concerned that refuge chambers and contents (breathable air cylinders, gaskets, seals, food and water supplies,

etc.) are new to the mining industry and the longevity of these items has yet to be established.

9. Communications (29%) - Communications is critical for efficient and effective escape and rescue operations and the MINER Act requires that new communication systems be in place in the near future. Some mine operators have been utilizing communication systems with current technologies, but most are waiting for existing technologies to improve.

10. Secondary Explosions (24%) - It is not uncommon for an explosion to occur after an initial explosion or during the course of a mine fire. Mine operators utilizing inflatable chambers and safe havens are concerned that these units, when deployed, will not provide enough protection against a second explosion. A lesser concern is that refuge chambers may get thrown or flipped over from the violent force of an explosion. One mine operator, using steel chambers, has decided to anchor the chambers to the mine floor after each move.

11. Tampering with Refuge Chambers and/or Contents (19%) - Mine operators are concerned that miners may tamper with the refuge chambers and/or remove some of the contents and put the refuge chamber out of commission until the contents can be repaired or replenished. Several mines will be utilizing a specialized or unique zip tie to better be able to detect tampering.

12. Damage from Being Deployed (19%) - As seen in the picture of the deployed inflatable refuge chamber (shown previously in this report), it is evident that the tent can occupy a large volume when deployed. Mine operators are concerned that steel wires from roof screen, cable bolts, roof bolts, or other protruding objects may puncture the tent portion of the chamber.

13. Extra Manpower to Move and Maintain (19%) - All the activities associated with the new refuge alternatives including relocating the refuge chambers and safe haven materials, preparing and reinforcing the new locations, hanging signs, updating the mine maps, inspecting, and maintaining create a greater demand on mine operators for more time and manpower.

14. Temperature Inside of the Chamber and Psychological Effects of Occupancy (10%) - As the depth of cover increases, so does the ambient temperature inside of a coal mine. Mine operators, with very deep mines and high ambient temperatures, are concerned that the temperature inside the refuge chambers may get excessively hot if the chamber is deployed at the maximum person capacity. One mine has ordered an inflatable chamber with a larger containment area to lower the inside air temperatures.

	Refuge Alternative				Reasons for Selection											Concerns / Challenges														
Company/ # Mines/ Mine Type (LW or R&P)	Steel (Rigid) Chamber (S)	Inflatable Chamber (I)	Safe Haven (H)	**Capacity (# persons)**	Cost	Protection from Secondary Explosion	Rapid Deployment	Capacity	Maneuverability (Size)	Physical Integrity - Moving	Physical Integrity - Deployed	Physical Integrity - Initial Explosion	CO2 Scrubbing System	Insufficient Information on Chambers	Ease of Training	Lack of Expertise - Training and Inspection	Poor Decisions in Escape vs. Rescue	Temperature Inside Chamber and Psychological Effects	Secondary Explosions	Tampering	Changing Legislation / Regulations	Storage of High Pressure O_2 Cylinders	Damage (Moving)	Damage (Deployed)	Longevity of Chamber and Contents	Environment (bad roof/rib, water, temp)	Extra Manpower to Move and Maintain	Communications	Moving: Increased Risk of Injury
Coal Mines with Mining Height > 60"																														
1 / 1 / LW	**S**			16		**S**				**S**													**S**	**S**		**S**			
2 / 1 / LW	**S**			16-24		**S**				**S**	**S**												**S**		**S**				**S**
3 / 1 / LW		**I**		20	**I**		**I**		**I**	**I**			**I**			**I**	**I**		**I**			**I**	**I**		**I**				**I**
4 / 2 / R&P		**I**		35	**I**			**I**								**I**	**I**		**I**	**I**			**I**		**I**	**I**	**I**		**I**
5 / 14 / LW, R&P			**H**	24	**H**				**H**				**H**	**H**		**H**					**H**	**H**							
6 / 9 / LW, R&P		**I**		36					**I**	**I**						**I**			**I**	**I**			**I**	**I**					
7 / 2 / LW, R&P		**I**		25						**I**							**I**	**I**			**I**		**I**		**I**	**I**			
8 / 1 / LW			**H**	16	**H**				**H**					**H**		**H**					**H**							**H**	
9 / 1 / R&P		**I**		20	**I**				**I**							**I**	**I**				**I**								
10 / 1 / LW	**S**			26		**S**				**S**													**S**						**S**
Coal Mines with Mining Height < 60"																														
11 / 6 / R&P	**S**			20		**S**				**S**						**S**				**S**			**S**			**S**			
12 / 10 / R&P			**H**	24	**H**			**H**						**H**		**H**					**H**	**H**	**H**			**H**			**H**
13 / 1 / R&P	**S**			20		**S**				**S**	**S**				**S**	**S**	**S**						**S**			**S**			
14 / 8 / R&P		**I**		24-30				**I**	**I**						**S**	**I**					**I**	**I**	**I**	**I**		**I**	**I**	**I**	**I**
15 / 4 / R&P		**I**		30				**I**	**I**	**I**						**I**						**I**				**I**		**I**	
Coal Mines with Mining Height < and > 60"																														
16 / 3 / R&P		**I**		30	**I**			**I**	**I**	**I**						**I**			**I**	**I**		**I**	**I**	**I**		**I**		**I**	
17 / 16 / R&P		**I**		20			**I**		**I**	**I**						**I**	**I**											**I**	**I**
18 / 5 / R&P		**I**		26			**I**	**I**	**I**	**I**						**I**	**I**						**I**		**I**	**I**		**I**	**I**
19 / 7 / R&P		**I**		16-20				**I**	**I**	**I**						**I**	**I**		**I**		**I**	**I**	**I**				**I**		**I**
20 / 5 / LW, R&P		**I**		26				**I**	**I**	**I**				**I**		**I**						**I**	**I**		**I**	**I**	**I**		**I**
21 / 7 / LW, R&P		**I**		20-36					**I**	**I**		**I**					**I**	**I**					**I**		**I**				
Totals	**5**	**13**	**3**		**7**	**5**	**3**	**8**	**13**	**15**	**2**	**1**	**2**	**4**	**1**	**16**	**9**	**2**	**5**	**4**	**7**	**8**	**16**	**4**	**7**	**11**	**4**	**6**	**10**