Foster-Miller Report No: NSH-080020-1864

Refuge Alternatives in Underground Coal Mines

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December 2008

Period Covered: 04/15/07 – 12/15/08
Final Report – Volume II
Contract Number: 200-2007-20276

Prepared for:

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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Appendix A. Summaries of Data Collection from Past Accidents or Disasters

This appendix contains detailed reports and analysis covering the 42 fatal mine disasters from 1970 to 2006.

Data is provided in three parts: Major disasters (five or more miners killed) from 1970 to 2006; disasters from 1970 to 2006 involving fatalities in which less than five miners were killed; disasters that are not directly applicable to current intended use of refuge stations, but may have elements that may become relevant to designing, locating or establishing the usefulness of refuge stations. In all three parts, disasters are presented in descending chronological order.

Data is summarized from disaster reports provided from MSHA archives and their website. In many cases, it was necessary to make certain assumptions with regard to data available. This has been noted where applicable in the tables below.

Major disasters from 1970 to 2006 (five or more miners killed):

1. **Kentucky Darby, LLC, Darby No. 1 Mine (ID No. 15-01815)**
   May 20, 2006; Explosion (5 Fatalities)

First indication of fire, explosion or inundation	1:00 am May 20 explosion in sealed A Left Section
Death of Miner 1, Miner 2, …., etc.	Two miners cutting steel roof strap with torch at No. 3 Seal caused methane mixture inby the seal to ignite. The resulting methane explosion killed both miners instantly.
First knowledge of accident outside mine	Immediately after the explosion gusts of air, dust and debris blew out the portals
First knowledge of accident elsewhere inside mine	Group of four miners in B Left Section immediately adjacent to A Left Section felt a pressure pulse almost immediately.
Actions and movements of the miners inby (downstream) of fire or explosion	Four Miners boarded two personnel carriers and began traveling outby in the primary escape way. Encountered dense smoke four crosscuts outby the section power center approximately 350 ft from the working face. All 4 miners donned SCSRs and boarded a single personnel carrier and continued traveling outby another 300 ft. Personnel carrier encountered debris from a ventilation overcast damaged by the explosion. Miners exited the personnel carrier and walked approximately 200 ft more to the power center 1 crosscut inby the No. 4 belt drive. At this point they were 850 ft outby the face of the B Left Section and approximately 3300 ft from the outside of the mine. One miner followed the power cable in the No. 5 entry for approximately 1050 ft before collapsing (the No. 5 entry is not the primary or secondary escape way). After regaining consciousness at approximately 3:05 am, he crawled into the No. 6 entry (an intake airway) where he was

	found by rescuers. The other three miners were overcome by smoke and CO and died. Each was found at different locations outby the No. 4 belt drive. Two were in the No. 5 entry. The third was outby the belt drive in a crosscut between the entries No. 2 and No. 3, both return air courses. None of the miners were in either the primary or secondary escape ways outby the No. 4 belt drive.
Actions and movements of miners (outby) upstream of fire or explosion	All other miners had exited the mine minutes before the explosion.
Miners barricade	No attempt to barricade. Two died instantly. Four attempted to escape.
Rescue team enters mine	2:32 am on 5/20 barefaced initially but had to go under oxygen when high CO levels were encountered further inby.
Rescue team reaches miners	Reached sole survivor at 3:10 am. Miner was wearing SCSR, no nose clips, and goggles. Reached first victim at 4:30 am, victims No. 2 and 3 at 5:16 am, victim No. 4 at 8:45 am, and victim No. 5 at 8:50 am. All three of the victims who did not die instantly were wearing their SCSRs, but no nose clips or goggles.
All miners and rescue team are out of mine	All bodies out of the mine by 10:55 am on 5/20/2006
Distance of working section from surface of mine	4300 ft
Extent of flame	All of the flame was inside the originally sealed A Left section. No evidence of flame outside original seal locations. Virtually all flame due to methane with some evidence of coal dust involvement inside the original sealed area.
Extent of forces	Force of the explosion destroyed all three Omega block seals. Force caused personnel carrier to be thrown 260 ft. Bodies of two miners were thrown 240 ft and 340 ft. Forces severely damaged a ventilation overcast at the mouth of the A Left section and other ventilation structures. Debris was blown out of the portal. Miners in A Left, however, only felt a pressure pulse that didn't have enough force to knock anyone off their feet. MSHA estimated forces outby the seals of at least 22 psi.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* YES - Portable refuge chambers within 1000 ft of the face as required by WV would have been within 200 ft outby the No. 4 belt drive power center (this is where decision was made to follow the power cable). Lifelines would have been useful to guide the miners to the stations. Breathable air supplies as required by MSHA would have been within 1200 ft of the power center.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption:* YES - any refuge stations within the 1000 ft of the face, as currently required by WV, would have been exposed to forces exceeding 22 psi.

If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumption:* stations placed according to WV and MSHA guidelines would have been viable and easily reachable for miners wearing SCSRs. A lifeline would have been useful to guide miners to the stations. Rescue teams would have reached the station within several hours after the explosion.
Miscellaneous Comments	*FMI assumption:* this is a good example of how refuge stations would have had a positive impact.
Total number miners underground at the time of the accident	Six
Number of miners impacted by the accident versus not impacted	All six impacted
Of those miners impacted, number immediately killed	Two were killed instantly; three died trying to escape
Of those miners impacted, number that escaped and evacuated	One escaped to fresh air and was rescued
Of those miners impacted, number that barricaded	No attempt to barricade
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Two miners killed instantly were neutrally affected. Four miners not killed instantly would have been positively affected by a station (all four would have survived instead of just one)
Miners that escaped, escaped within what timeframe?	None escaped to the surface; one escaped to air clear enough to survive and be rescued by rescuers at 3:10 am – 2 hr, 10 min after the explosion
Miners that died, died within what timeframe?	Not known, though the first body was found at 4:30 am, 3 hr, 30 min after the explosion
Miners that were rescued, were rescued within what timeframe?	The sole survivor was rescued by rescuers at 3:10 am – 2 hr, 10 min after the explosion

2. Wolf Run Mining Company, Sago Mine (ID No. 46-08791) January 02, 2006; Explosion (12 Fatalities)

First indication of fire, explosion or inundation	6:26 am January 2; explosion in sealed 2 Main North Section
Death of Miner 1, Miner 2, …., etc.	A lightning strike caused a methane mixture in by the seals to ignite. A methane explosion killed one miner instantly. Twelve other miners were unable to escape and barricaded. Eleven of the twelve died from CO poisoning.
First knowledge of accident outside mine	Immediately after the explosion the dispatcher heard a pop on the mine phone and the AMS system alarmed and showed high CO levels.

First knowledge of accident elsewhere inside mine	Several miners outby felt air rushing and saw dust in the air. Miners in the No. 1 Left Section crew felt a violent blast of air, thick dust and debris in the air. The blast knocked off hard hats, lights, and glasses. Miners did not hear explosion or see flash. Air monitor alarmed but miner could not see the display. After the air rush, miners felt heat.
Actions and movements of the miners inby (downstream) of fire or explosion.	Twelve miners boarded the battery powered track mounted mantrip and began traveling outby after attempting unsuccessfully to call outside. Encountered smoke. Continued outby but were stopped by debris on the track (identified as pieces of a blown out Omega block seal). Miners exited mantrip, donned SCSRs, and continued outby on foot. Miners were in smoke but not dense enough to cause them to attach to each other. At some point they concluded that escape wasn't possible and they decided to retreat and barricade. Miners built two barricades using ventilation curtain but they were not well sealed. Miners removed self rescuers during construction then re-donned after construction. After 1 to 1/2 hr, two miners left the barricade to check conditions. Reentered choking and gagging from smoke. Over time 11 of 12 miners died from CO poisoning. The 12th miner was near death but survived and was rescued.
Actions and movements of miners (outby) upstream of fire or explosion	Thirteen miners in No. 1 Left Section evacuated by walking out the track entry in thick dust with poor visibility. Debris from the effects of the explosion prevented use of the mantrip. Primary escape way was contaminated with smoke. Moved into primary escape way when air cleared and contacted surface by phone at 6:32 am. Crew met a mantrip bringing management personnel into the mine at 7:00 am and 12 were transported to the surface arriving at 7:20 am. One miner stayed underground to attempt rescue of No. 2 crew. Only 7 of 13 had donned self rescuers. Other outby miners safely evacuated on foot or on the mantrip with the No. 1 left crew.
Miners barricade	After attempting escape, miners retreated and erected two curtain barricades. It's estimated that miners completed and entered the barricade by 7:15 am.
Rescue team enters mine	Mine management personnel entered the mine with no air monitoring instrument or air supply to attempt location and rescue of missing miners. First rescue team entered the mine at 5:25 pm on 1/02/06.
Rescue team reaches miners	Reached first victim at 5:15 pm on 1/03/06. Reached barricade at 11:45 pm on 1/03/06. 11 of 12 miners inside the barricade were deceased. One surviving miner was transported to surface by rescue team.
All miners and rescue team are out of mine	Rescue team with sole survivor reaches surface at 1:00 am on 1/04/06. All bodies out of the mine by 10:00 am on 1/04/2006.

Distance of working section from surface of mine	Approximately 13,500 ft.
Extent of flame	All of the flame was inside the originally sealed 2 North Main Section. There was little evidence of flame outside original seal locations. Virtually all flame due to methane with some evidence of coal dust involvement inside the original sealed area.
Extent of forces	Force of the explosion destroyed all ten Omega block seals. Force estimated to exceed 93 psi. Miners in both underground sections were exposed to approximately 2 psi. Ventilation structures outby the seals suffered significant damage typical of pressures over 2 psi. The deceased miner located approximately 500 ft outby the blown out seals did not exhibit traumatic physical injuries, indicating pressures at that location did not exceed 5 psi.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption*: YES – Portable refuge chambers within 1000 ft of the face as required by WV would have been 1500 ft inby the mouth of the section and the breathable air supply as currently required by MSHA would have been at 2000 ft. Both easily reachable by the miners. A lifeline would have helped guide miners, particularly to the outby station.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption:* YES – Any refuge stations within 1000 ft of the face as currently required by WV would have been exposed to forces as high as 2 psi and any station 2000 ft outby would have been inby the mouth of the section less than 500 ft and less than 1000 ft from the seals that were blown by forces estimated to be 93 psi. Forces at a station at this location may have been as high as 15 to 20 psi.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	Viable and reachable for miners wearing SCSRs. Lifelines would have been useful to guide the miners to the station.
Miscellaneous Comments	This is a good example of how stations would likely have had a positive impact.
Total number miners underground at the time of the accident	Twenty-nine
Number of miners impacted by the accident versus not impacted	Most of the 29, many escaping through smoke and gasses
Of those miners impacted, number immediately killed	One
Of those miners impacted, number that escaped and evacuated	All 16 survivors not trapped in the mine escaped to the surface
Of those miners impacted, number that barricaded	Twelve

Number of barricaded miners rescued alive	One
Number of barricaded miners that died	Eleven
No. miners that could have been positively, negatively, neutrally affected by stations	Twelve would have been impacted positively, none negatively or neutrally
Miners that escaped, escaped within what timeframe?	Within about 1 hr (explosion at 6:26 am, evacuated miners were out by 7:20 am)
Miners that died, died within what timeframe?	Sometime after 10 hr (explosion at 6:26 am, last discussion of life in barricade per written notes by miners was about 4:25 pm; death came sometime after that)
Miners that were rescued, were rescued within what timeframe?	Within about 41 hr (explosion at 6:26 am January 2; rescue at 11:45 pm on January 3)

3. Jim Walters Resources, Inc., No. 5 Mine, (ID No. 01-01322) September 23, 2001; 2 Explosions (13 Fatalities)

First indication of fire, explosion or inundation	5:20 pm, first of two explosions in No. 4 Section; 6:15 pm, 2nd larger explosion
Death of Miner 1, Miner 2, …., etc.	A roof fall caused a sudden release of methane and a short in an electrical cable triggering the first of two explosions. The small methane explosion injured four miners who were building cribs in the crosscut where the explosion occurred. Three of the miners escaped the section on a locomotive. The fourth was too injured to be moved. The first explosion damaged section ventilation structures allowing methane to accumulate. Other miners traveled to and into the 4 Section to rescue the injured miner. This was not the trained mine rescue team. No one carried a gas detector. A second, much larger explosion involving both methane and coal dust occurred at 6:15 pm killing all 13 miners in the 4 Section or near the mouth of 4 Section. No mine wide-evacuation order had been given after the first explosion.
First knowledge of accident outside mine	The first explosion caused loss of signal from AMS sensors in 4 Section. Call from underground from one of the injured miners from 4 Section was made at 5:45 pm.
First knowledge of accident elsewhere inside mine	Miners near 4 Section felt a pressure pulse from the first explosion. Air in the longwall became dusty. The second explosion caused fatal injuries to miners in and near the mouth of 4 Section. Other miners underground were knocked off their feet or fell to the ground because of the concussive forces. Thick dust cloud.
Actions and movements of the miners inby (downstream) of fire or explosion.	Three of the four miners in 4 Section boarded a locomotive and proceeded out the intake escape way. All three were injured. Only one attempted to don an SCSR but dropped it. Drove to mouth of section to

	damaged overcast. Fourth miner was severely injured and couldn't be moved. There were no other miners in 4 Section.
Actions and movements of miners (outby) upstream of fire or explosion	There was no mine-wide evacuation ordered after the first explosion. At approximately 5:50 pm there was significant dust in the intake of the longwall panel and the crew started evacuation. Did not don SCSRs even in "thick" dust. Other miners, instead of evacuating, went to 4 Section to investigate, and rescue the injured miner. No gas detectors found with rescuers. Miners were told to turn off power to the affected 4 Section, but the track haulage block light system remained energized and was the ignition source for the second explosion.
Miners barricade	No attempt to barricade. Twelve miners died almost instantly from forces, burns, and asphyxiation. 13th was severely injured when found by rescuers and died the next day.
Rescue team enters mine	8:05 pm on 9/23/2001
Rescue team reaches miners	Found sole surviving injured miner at 10:15 pm. He reached the surface at 11:30 pm. Found first three victims at approximately 10:45 pm. Decision made that other nine missing miners also dead and conditions too dangerous to continue recovery. Rescue teams ordered to evacuate at 6:25 am and were at the surface by 7:09 am on 9/24. Area of mine impacted by the explosion was flooded to put out remaining fires.
All miners and rescue team are out of mine	Mine dewatered and recovery restarted on 11/3/2001. Three victims removed to the surface on 11/3. The other nine victims were located and removed on 11/7/2001.
Distance of working section from surface of mine	Likely several thousand feet to the portal. There was a vent shaft approximately 2000 from where the explosion occurred but there was no hoist in the shaft.
Extent of flame	Only a small amount of methane was involved in the first explosion and flame only extended 70 ft. The second explosion flame front traveled outby over 1200 ft to the mouth of Section 4. The flame then traveled inby into 6 Section approximately 900 ft, outby in 3 East approximately 1200 ft, and over 600 ft to Shaft 5-9.
Extent of forces	Force of first explosion damaged ventilation structures including overcast at the mouth of Section 4. Miners in the vicinity were knocked off their feet and injured. The second explosion was much larger and involved dust. MSHA estimated forces in Section 4 of at least 12 psi. Forces outby the mouth of Section 4 diminished but were still high enough to cause extensive damage to ventilation structures in both 6 Section and 3 East.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption :* NO – The miners who survived the initial explosion were able to escape to the mouth of the section without SCSRs. The one severely injured, and possibly dead, was left behind. The second explosion killed 12 of the 13 miners in and near 4 Section almost instantly. The 13th found alive by the rescuers died the

	next day due to the severity of his injuries, not CO poisoning. The other miners farther outby escaped after the second explosion without SCSRs.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A.
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Thirty-two
Number of miners impacted by the accident versus not impacted	Sixteen directly impacted; 16 not directly impacted (though all felt the explosions and saw dust, etc.)
Of those miners impacted, number immediately killed	One maybe killed immediately after the first explosion; 11 plus the original one definitely killed instantly after the second explosion = 12 TOTAL
Of those miners impacted, number that escaped and evacuated	Three miners injured on the first explosion escaped and evacuated. Nineteen exited the mine after the second explosion.
Of those miners impacted, number that barricaded	None – Three miners injured in first explosion escaped and 12 were killed instantly in second explosion
Number of barricaded miners rescued alive	N/A – none barricaded, but one injured miner was rescued alive
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Thirteen miners neutrally (12 died instantly and one was too injured to be able to move to a station). Three injured were neutrally affected because they escaped.
Miners that escaped, escaped within what timeframe?	The report is not specific on times. The three miners that escaped after the first explosion phoned outside about 5:45 pm, 25 min after the 5:20 explosion and so had likely escaped to a safe area by then. The 19 miners that evacuated after the second explosion presumably left soon after the second explosion occurred at 6:15 pm.
Miners that died, died within what timeframe?	Twelve died instantly; one injured miner died the following day after being rescued from the mine.
Miners that were rescued, were rescued within what timeframe?	The sole injured miner was rescued and arrived at the surface at 11:30 pm almost 6 hr after the first explosion

4. Southmountain Coal Co., Inc. - No. 3 Mine (ID No. 44-06594) December 7, 1992; Explosion (8 Fatalities)

First indication of fire, explosion or inundation	6:15 am December 7 in 1 Left section
Death of Miner 1, Miner 2, …., etc.	All miners were in 1 Left and died instantly from the coal explosion that immediately followed the original methane explosion
First knowledge of accident outside mine	After 6:20 am December 7
First knowledge of accident elsewhere inside mine	N/A – Only one group in the mine
Actions and movements of the miners inby (downstream) of fire or explosion.	N/A – All appeared to have died instantly following the coal dust explosion that immediately followed a methane explosion
Actions and movements of miners (outby) upstream of fire or explosion	One miner was outby at a belt drive and was able to crawl out of the mine (though he had suffered burns from the heat of the explosion)
Miners barricade	N/A – Died instantly.
Rescue team enters mine	10:30 am, December 7 but had to retreat due to high methane readings
Rescue team reaches miners	Reached seven of eight bodies at 7:46 pm on December 9; reached final body at 7:00 pm on December 12
All miners and rescue team are out of mine	All bodies out of the mine by 8:57 pm December 12.
Distance of working section from surface of mine	6000 ft
Extent of flame	Mine map unavailable but verbal discussion states that flame from the coal dust explosion extended from 1 Left to the surface of the mine. Flame from the initial methane explosion was estimated to extend about 700 ft and was limited to 1 Left, not extending into the Mains
Extent of forces	Mine map unavailable but verbal discussion states that primary forces from the original methane explosion were relatively low in 1 Left (about 5 psi). Secondary forces from the coal dust explosion were much greater, averaging 17 psi heading outby along the Mains and 10 to 12 psi back into 1 Left.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO. Stations would NOT have helped in this situation due to the violence of the coal dust explosion and the immediate death that ensued.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A

If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Nine
Number of miners impacted by the accident versus not impacted	All nine impacted
Of those miners impacted, number immediately killed	Eight
Of those miners impacted, number that escaped and evacuated	One
Of those miners impacted, number that barricaded	None (all killed immediately except one outby miner who escaped)
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Eight would have been neutrally affected because stations were N/A in this situation. One miner who escaped in neutrally impacted.
Miners that escaped, escaped within what timeframe?	The one outby miner exited the mine immediately
Miners that died, died within what timeframe?	All eight died immediately
Miners that were rescued, were rescued within what timeframe?	N/A – None rescued

5. Pyro Mining Co., William Station Mine, Pyro No. 9 Slope Mine (ID No. 15-13881) September 13, 1989; Coal Mine Explosion (10 Fatalities)

First indication of fire, explosion or inundation	9:13 am September 13, explosion was witnessed by, and immediately affected, the miners working on the "O" LW panel equipment teardown and recovery between 4th West and 5th West sections.
Death of Miner 1, Miner 2, …., etc.	The report does not provide a timeline of the death of the 10 miners. Immediately after the blast, scoop operator Furgerson called out that he was hurt but didn't respond after that. As miners were escaping, they encountered others lying on the ground with their FSRs out of their mouths and attempted to help them. Some miners were apparently still alive but not able to escape due to unconsciousness. Ultimately, four escaped the

	relatively short distance to clear air while six didn't make it out (and four more were unaccounted for until more extensive recovery started later on). Most of the miners appeared to don their FSRs but some had later removed them to communicate. Intense heat and dense smoke disoriented and overwhelmed some of the miners. The four who escaped appeared *not* to have removed their FSRs to attempt to communicate.
First knowledge of accident outside mine	Shortly after 9:00 am a call to the surface indicated an air blast and loss of power. All underground units responded to subsequent calls to check on them except the LW recovery crew. During these calls, a miner broke in with a report of the explosion.
First knowledge of accident elsewhere inside mine	Once the explosion was reported (see above), an immediate evacuation of all units was ordered (except that the LW recovery unit couldn't be reached).
Actions and movements of the miners inby (downstream) of fire or explosion.	Movements of the 10 miners in the No. 3 Recovery Room area are documented in the report. The four who escaped made it to the 4th West entries (intake and/or track) and continued out to fresh air in the track entry. The other 6 miners from the recovery room area who didn't make it out appeared to either have been too injured or too overcome and disoriented through a combination of attempting to help others and removing their FSRs to communicate with each other. The report does not attempt to discuss movements of the four miners in the LW face area. They were found later on in their work areas. All had been burned. The report does not speculate on their deaths but (*FMI assumption*) they likely died quickly or were too injured to attempt to escape.
Actions and movements of miners (outby) upstream of fire or explosion	All miners in all other areas of the mine (who did not immediately go help in 4th West) were able to evacuate without incident.
Miners barricade	No attempt to barricade.
Rescue team enters mine	Attempted rescue and recovery was begun soon after the explosion by the survivors and by others in the mine who traveled to 4th West after hearing of the explosion. The report does not give a timeline for these efforts but they were begun fairly quickly (within an hour or so??). An official rescue team arrived and proceeded underground at 12:23 pm but all victims had been recovered and ventilation established in the recovery rooms and along the LW face by the time they arrived at 4th West.
Rescue team reaches miners	See above.

All miners and rescue team are out of mine	All rescue and recovery efforts of the victims were complete and most miners involved left the mine before the official rescue team had arrived on section (some time after 12:23 pm).
Distance of working section from surface of mine	Unknown without detailed mine maps not included with the report.
Extent of flame	Flame propagation was extensive in the No. 2 entry (and crosscuts) of the 4th West entries and it extended along the longwall face being recovered but was not a factor within the recovery rooms where most of the miners were located. The four miners along the LW face, however, were burned by the flame.
Extent of forces	Maximum forces were about 10 psi near the No. 10 crosscut and no miners were near that area. Forces dissipated outby and were very minimal in the recovery room area where most of the miners were located (1 to 2 psi). The scoop operator might have been subjected to 5 psi but his death was deemed due to smoke and soot inhalation and not from the forces. No specific mention was made about the forces on the four miners located on the LW face, but presumably the forces were also not a factor in their deaths.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption*: YES. Miners overwhelmed and exhausted would have likely made it to the station and survived. However, with lifelines, they may have been able to make their way the relatively short distance outby to fresh air along with the four miners who successfully escaped.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption:* depending on where a station would have been located, it could have been exposed to forces though they would have been minimal. In this particular case the station would probably NOT have needed to be explosion-proof.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumptions*: placement per WV and MSHA guidelines would have been OK. The escape ways along the mains in which the stations would have been located were the intake and track entries and the miners who successfully escaped did so along the track entry.
Miscellaneous Comments	*FMI assumptions*: Some or all of the miners who died might have used a lifeline to make it to the station to regroup. Even if the station had been located much further outby, a lifeline might have directed those miners far enough outby to get into fresh air before reaching the station.

Total number miners underground at the time of the accident	The report does not say how many men were in the mine at the time of the accident.
Number of miners impacted by the accident versus not impacted	Fourteen impacted; all others in mine (number unknown) were not affected
Of those miners impacted, number immediately killed	Ten were killed, though at least six not immediately (less is know of the other four – assumed killed immediately)
Of those miners impacted, number that escaped and evacuated	Four escaped to fresh air
Of those miners impacted, number that barricaded	None attempted; died immediately or in the process of attempting to escape
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Up to 10 (four that escaped and six not immediately killed) exhausted, disoriented miners might have used a station for short-term comfort during the escape (positive).
Miners that escaped, escaped within what timeframe?	Report is not specific but all sections of the mine were notified to evacuate very soon after the explosion occurred and the evacuation of unaffected miners would have progressed quickly. The first rescue team entered the mine about 12:23 pm. No timeline is provided on the four affected miners that escaped.
Miners that died, died within what timeframe?	Report does not provide a timeline on the deaths.
Miners that were rescued, were rescued within what timeframe?	N/A - no miners were rescued

6. Emery Mining Corp, Wilberg Mine (ID No. 42-00080) December 19, 1984; Fire (27 Fatalities)

First indication of fire, explosion or inundation	Shortly after 9:00 pm December 19 smoke seen in mains by a miner (Salisbury) near the mouth to 5th Right LW panel. About 9:15 another miner saw fire and smoke. [NOTE that personnel within the 5th Right panel were the victims of the fire.]
Death of Miner 1, Miner 2, …., etc.	The report does not attempt to timeline the death of the 27 miners. Many of the miners donned SCSRs, some successfully and some not and some did not don them at all. Some miners appeared to have used their SCSRs to depletion. Hence (*FMI assumption*) it appears that considerable time may have elapsed

	between realization of the fire and death of some of the miners who successfully used SCSRs. Others probably died much earlier because of the failure to don SCSRs. The sole survivor traveled for some time through the smoke filled entries and eventually made it to clear air but the report does not say how long that took.
First knowledge of accident outside mine	Shortly after 9:00 pm December 19 a miner reported smoke to the outside warehouseman who patched the conversation to 5th Right section. Miners on 5th Right gave no indication of seeing smoke on the section but said they'd check it out. Slightly later (before 9:30??-report is not specific), Salisbury confirmed smoke and flames and called outside again to report it.
First knowledge of accident elsewhere inside mine	After the second confirmation by Salisbury (before 9:30??), outside warehouseman notified all miners within the mine and general evacuation began.
Actions and movements of the miners inby (downstream) of fire or explosion.	After receiving confirmation of the fire, some miners started across LW panel to tailgate to warn miners on the panel to evacuate and to get the SCSRs at the tailgate. Other miners started evacuating out the belt entry (headgate side). The intent was for everyone to escape out the beltway. One miner entered the intake entry to look for SCSRs but found it thick with smoke. Soon the beltway also became filled with thick smoke. Many miners advanced to crosscut 5 about 1,750 ft outby the headgate and realized at that point that both the intake and belt entry escape ways were blocked. Two miners entered the adjacent "dogleg" entry, also filled with smoke, to try to escape that way while other miners apparently intended to head back across the panel to the return entry at the tailgate. The two miners who entered the dogleg together became separated and only one of them (Blake) went far enough to pass through a mandoor into the main entries and eventually to clear air. Blake was the only survivor. The miners waited for the second call to the section that confirmed a fire before taking action. Within 2 or 3 min after that second call, the headgate filled with heavy smoke. The report states that this delayed reaction in taking the situation seriously and starting to seek and don SCSRs, etc. had a major impact on the disaster.
Actions and movements of miners (outby) upstream of fire or explosion	No miners upstream of the fire were affected by the fire or smoke. Most miners in the mine evacuated without incident while others remained inside to fight the fire and begin search and rescue of the miners in 5th Right. All miners other than those trapped in 5th Right (and Blake) survived the fire.
Miners barricade	No evidence of attempting to barricade.
Rescue team enters mine	Initial rescue was attempted by the LW coordinator by entering the dogleg entry (wearing an SCSR) between 10:30 and 11:00 pm December 19, but he retreated due to heavy smoke without seeing any victims. Other miners explored bleeder entries and the 6th Right return

	entry for the 5th Right panel but roof falls and breathing problems ended their explorations and no victims were found. The first mine rescue team entered the mine about 11:50 pm December 19 and the first exploration of 5th Right started about 11:00 am December 20 in the dogleg entry. Heavy smoke and apparatus problems halted the advance without any victims being found.
Rescue team reaches miners	NO miners barricaded. All miners accounted for below were victims: *Nine miners:* about 5:30 am December 21, with the fire under control, a rescue team explored to crosscut 5 in the dogleg entry and found the first nine victims. *Four miners:* about 4:00 pm December 21, four victims found between crosscuts 5 and 7 in the belt entry *Five miners:* at 6:15 pm December 22, five victims found near the LW headgate *One miner:* at 6:46 pm December 22, one victim found at the "kitchen" in crosscut 21 *One miner:* at 7:05 pm December 22, one victim found in crosscut 20 in the intake entry *Three miners:* at 7:25 pm December 22, three victims found under the first three shields on the LW panel *Two miners:* at 9:10 pm December 22, two victims found in the return entry *Two miners:* December 16, 1985, nearly a year after the fire, final two victims found, one in the return and one in the bleeder entries.
All miners and rescue team are out of mine	N/A for this discussion. A general mine evacuation was completed soon after the confirmation of the fire by Salisbury. This would have happened fairly quickly and without incident. The rescue teams made numerous entries into, and evacuations from the mine, throughout the search and recovery operations based on the fire spreading out of control and being brought back into control. Ultimately the fire raged out of control, the mine had to be sealed and bodies were not removed for nearly a year.
Distance of working section from surface of mine	Distance from the headgate of 5th Right to the mouth of the panel was about 2,300 ft. Distance from the mouth of 5th Right to the surface of the mine is not known since detailed mine maps were not provided with the .pdf report. The report does state that "main and submain entries were driven to the north for 9,600 ft...", so surface to 5th Right off the North Mains was likely less than 9,600 ft.
Extent of flame	Flame from fire only (not explosion) – The report discusses various witness accounts of the fire flames extending throughout numerous areas of the mouth of 5th Right but the flames did not appear to have directly affected the travel paths of the miners along the intake and beltway of 5th Right or the dogleg entry. The miners were certainly subjected to some degree of heat from the flames.

Extent of forces	N/A - no explosion.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption*: YES – Stations (or a station within reach of the LW section) would definitely have helped the miners survive by providing a haven with breathable air. Most of the miners died after some time of moving about the section looking for an escape, realizing there was not one immediately available and expiring due to lack of breathable air. Although one miner escaped completely, he barely made it and he made it via a path that would not have been generally known to be available, so the miners could not have been expected to follow him through this path.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	NO – This was not an explosion and no forces were involved.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumptions*: placement per guidelines would have been OK. Miners attempted to travel outby and a lifeline from the headgate guiding them to a station in or between the intake or belt entries would have been perfect.
Miscellaneous Comments	None
Total number miners underground at the time of the accident	About 80
Number of miners impacted by the accident versus not impacted	Twenty-eight impacted; about 52 not impacted
Of those miners impacted, number immediately killed	Twenty-seven were killed, none immediately; the report does not timeline the deaths
Of those miners impacted, number that escaped and evacuated	One
Of those miners impacted, number that barricaded	None attempted
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All 28 miners impacted would have likely been positively affected by a station
Miners that escaped, escaped within what timeframe?	All unaffected miners evacuated following instructions about 30 min after discovery of the fire. Time of arrival outside the mine is not provided in the report. A timeline for the sole affected miner who escaped the section is also not provided in the report.
Miners that died, died within what timeframe?	Timeline not discussed in the report (enough time elapsed that some miner's used up their SCSRs)
Miners that were rescued, were rescued within what timeframe?	N/A – No miners rescued

7. McClure No. 1 Mine (ID No. 44-04251)
June 21, 1983; Explosion (7 Fatalities)

First indication of fire, explosion or inundation	Approximately 10:15 pm, June 21, 1983, explosion occurred in 2 left section
Death of Miner 1, Miner 2, …., etc.	Report does not have exact times of death for each miner, but it appears from the evidence that the 10 miners involved were in two groups: 1. One group of eight miners were all located at the 2 Left, No. 40 crosscut working face, near the continuous miner and roof bolter machines. Of this group three miners survived the explosion, and five died, The medical report states that one miner died from head and chest injuries, and the other four from asphyxiation (CO inhalation). Of the three survivors, two were found conscious (one unconscious) by the rescuers, at approximately 1.5 hr after the explosion. There was no mention of whether they had used their filter type self rescuers. 2. The second group of two miners had been traveling outby in an electric (battery) personnel carrier and were found near 2 Left, No. 15 – 16 crosscut. They were close together but away from the personnel carrier. The report concludes that the men may have been thrown from the carrier, and it continued while slowing.
First knowledge of accident outside mine	Within a few minutes, phone calls were made to the mine surface by miners in other areas of the mine.
First knowledge of accident elsewhere inside mine	Immediately. Miners in other areas detected pressure change and saw dust clouds.
Actions and movements of the miners inby (downstream) of fire or explosion.	Explosion was an ignition of methane outby the working face and the first group of miners (above), concluded to be in 2 Left between crosscuts 25 and 37. The downstream (inby) miners that survived did not move more than 50 ft or so after the event, and were found close to each other. It was not noted whether their filter self rescuers were used.
Actions and movements of miners (outby) upstream of fire or explosion	The two miners found dead upstream (outby) of the explosion point were traveling outby in a battery personnel carrier at the time and were found inby of the carrier approximately 50 ft or so. Report concludes that the carrier could have continued on, slowing down after they were thrown from it. Report also suggests that electrical arcing caused the ignition, and the personnel carrier is one of a list of possible items that caused the ignition. The ignition point appears to have been somewhere between the two groups of miners. It was not noted whether they tried to use their filter type self rescuers.

Miners barricade	No attempt was made to barricade
Rescue team enters mine	First rescue team entered mine at approximately 11:45 pm, June 21.
Rescue team reaches miners	First miners found inby of explosion point, between approximately 12 and 1:00 am, June 22. Second group of miners found at approximately 1:30 am, June 22, outby of explosion point.
All miners and rescue team are out of mine	Approximately 5:15 am, June 22, all miners and rescuers out of mine
Distance of working section from surface of mine	Approximately 7000 ft (at the 2 Left entries)
Extent of flame	Total length of flame travel was approximately 12000 linear ft through entryways and crosscuts. Ventilation and dust analysis showed that 1/3 to 1/2 the total flame expansion was caused by burning coal dust, even though it had been inerted to 65% incombustible material. Gas analysis showed that explosive levels of methane were not present in all the areas that saw a flame front. These areas saw combustion of methane that was pushed there by the expansion of the gases, and the pressure wave that preceded the explosion. The total length of the explosive gas body was estimated to be in the range of 2000 to 2700 linear ft.
Extent of forces	The magnitude of the forces involved is consistent with a 6 to 6.5% level of methane, developing gage pressures from approximately 2 to 5 psi, and with a flame velocity of approximately 100 to 200 ft/sec. Burning coal dust contributed to flame spread, but a full propagating dust explosion did not occur. (A full coal dust explosion could produce flame speeds in excess of 800 ft/sec). Damage seen was slight, -dry stacked stoppings were collapsed (requiring only 1 to 2 psi), material and equipment dislocation was minimal.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* NO. It seems unlikely that the miners would have benefited from a refuge station with breathable air, and emergency supplies. This is based on the fact that the miners hardly moved (about 50 ft) from where they were before the explosion.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A

Miscellaneous Comments	FMI assumption: *(Several appendices , maps etc. were missing from the report as supplied to FMI.)* From the descriptions and diagrams given, it seems this was a relatively mild strength methane explosion, with some flame propagation provided from coal dust, but not a full coal dust explosion, however, the flame spread covered a very large area. Although it may appear that refuge stations would have been useful, the fact that the miners didn't move too far after the explosion indicates that it is very unlikely they would be able to get to a station even if it was at the nearest crosscut.
Total number miners underground at the time of the accident	Unknown – Report only details the 10 miners on No. 2 Left. Two other production crews and a 4-person timber crew were also working in the mine.
Number of miners impacted by the accident versus not impacted	Only the 10 miners in No. 2 Left were directly affected. All other crews recognized the explosion and saw some evidence of it (smoke, etc.) but were able to readily and safely evacuate.
Of those miners impacted, number immediately killed	Two were likely killed immediately; five died soon after from smoke and CO inhalation.
Of those miners impacted, number that escaped and evacuated	None of the 10 directly affected in No. 2 Left were able to escape and evacuate.
Of those miners impacted, number that barricaded	None attempted to barricade.
Number of barricaded miners rescued alive	None barricaded but three were rescued alive about 1.5 hr after the explosion.
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	The seven miners who died were neutrally affected (almost certainly would not have been able to make it to a station). Estimating approximately 30 total underground at the time of the incident, 23 survivors would have been neutrally affected.
Miners that escaped, escaped within what timeframe?	The report does not provide a timeline, but miners elsewhere (not part of No. 2 Left) began evacuating immediately after the 10:15 pm explosion and went straight to the elevator shaft. Some of these miners went back to assist in recovery sometime before 11:00 pm, so escape was made in less than 45 min.
Miners that died, died within what timeframe?	Report does not provide times but rescuers arrived to assist the survivors after about 1.5 hr, so the victims died sometime before that.
Miners that were rescued, were rescued within what timeframe?	1.5 hr after the explosion

8. RFH Coal Co., No. 1 Mine, (ID No. 15-12624)
January 20, 1982; Coal Dust Explosion (7 Fatalities)

First indication of fire, explosion or inundation	9:40 am, January 20 in No. 5 room, 001 section (rooms that had been turned right off the No. 7 entry)
Death of Miner 1, Miner 2, …., etc.	Autopsies showed that two miners died instantly due to the blast forces, and five died from CO poisoning an undetermined time later. The report does not state which miners died when.
First knowledge of accident outside mine	The mine manager heard the blast as it occurred, from the surface, at 9:40 am, January 20.
First knowledge of accident elsewhere inside mine	The entire mine was immediately affected. Only eight people in total were employed at the mine: Seven of them were underground at the time of explosion; all were killed.
Actions and movements of the miners inby (downstream) of fire or explosion	Unknown
Actions and movements of miners (outby) upstream of fire or explosion	Unknown
Miners barricade	No barricades were built
Rescue team enters mine	Rescue team entered at 12:50 pm, January 20
Rescue team reaches miners	The bodies were found at the following times/locations: (Time gaps occur while rescuers moved fresh air bases, and ventilated the entire mine): 4:08 pm: Three miners found in No. 4 room just off No. 7 entry. 9:01 pm: One miner found in No. 3 room just off the No. 7 entry. 9:11 pm: Two miners found between No. 2 room and No. 3 room in no. 7 entry. 11:37 pm: One miner found in No. 7 room just off the No. 7 entry.
All miners and rescue team are out of mine	All out of mine at 2:55 am, January 21.
Distance of working section from surface of mine	Approximately 1550 ft.
Extent of flame	Flame extended outby the No. 5 room to within 125 ft of the surface, and to just inby the last open crosscut of the main entries.
Extent of forces	Blast forces were massive. Forces damaged or destroyed all the concrete block stoppings underground. Explosion forces moved a 2 ton power center approximately 70 ft outby in the No. 6 entry. The main belt conveyor tailpiece that was at No. 4 entry, No. 16 crosscut before the explosion was moved outby 150 ft. At the surface portal, the mine ventilation concrete fan housing was damaged, all power cables ripped from wall. Inline with the surface opening, a 1000 gallon water tank was blown 50 ft onto an adjacent hill.

Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* NO for two reasons: First it is unlikely that minors could have survived a coal dust explosion and second, it is likely that any type of refuge station would be badly damaged.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	It is unlikely that any current refuge station design could withstand these excessive forces.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	Report concludes that this explosion was the result of misusing explosives for "slab shooting" to remove solid face sections in a room by placing explosive charges in strategically drilled boreholes. Slab shooting was done in a crosscut between two rooms, but a combination of factors including too much explosive, no "stemming" to confine the shot, insufficient water and rock dust placement, and recent blasting already done in the adjacent room caused a coal dust explosion when the shot blew through the dividing wall.
Total number miners underground at the time of the accident	Seven
Number of miners impacted by the accident versus not impacted	All seven impacted
Of those miners impacted, number immediately killed	Two were killed instantly and five died of CO poisoning an undetermined time later
Of those miners impacted, number that escaped and evacuated	None
Of those miners impacted, number that barricaded	None attempted
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Seven would have been neutrally affected because two were killed instantly and five others probably died soon after.
Miners that escaped, escaped within what timeframe?	N/A – None escaped
Miners that died, died within what timeframe?	Two were killed instantly and five died of CO poisoning an undetermined time later
Miners that were rescued, were rescued within what timeframe?	N/A – None rescued

9. Grundy Mining Co., No. 21 mine, (ID No. 40-00524) December 8, 1981; Explosion (13 Fatalities)

First indication of fire, explosion or inundation	Approximately 12 pm, December 8th in Section 003 of No. 21 Mine.
Death of Miner 1, Miner 2, …., etc.	Report concludes that all 13 miners in the section at the time were asphyxiated almost immediately. Victims were burned, but not physically badly damaged from the blast force. Explosion was an ignition of methane with a very minor involvement of coal dust in some areas. All miners were found within 150 ft of ignition source near the face. Report concludes methane had built up due to bad ventilation, and a cigarette lighter ignited it.
First knowledge of accident outside mine	Within a few minutes of the event, a call was placed to surface via mine telephone from other section miners aware of the event.
First knowledge of accident elsewhere inside mine	Almost immediately. A gust of hot air followed by airborne dust, and power outage in some sections alerted the miners to a possible explosion.
Actions and movements of the miners inby (downstream) of fire or explosion.	Miners were all at the site of explosion close to a working face. No movement inby was attempted. Twelve miners were moving in outby direction, and one miner was seated at controls of a shuttle car facing inby.
Actions and movements of miners (outby) upstream of fire or explosion	Report evidence concludes that the miners saw the burning gases just after ignition, since all except one miner were moving outby, and found with personal possessions behind them, inby. No miner had traveled more than 150 ft from the face. Evidence indicates that none of the victims attempted to use their self rescuers.
Miners barricade	None
Rescue team enters mine	2:20 pm, December 8th
Rescue team reaches miners	Approximately 6 pm, December 8th all miners found, all within 150 ft of coal face.
All miners and rescue team are out of mine	11:45 pm, December 8th, all personnel out of mine.
Distance of working section from surface of mine	Difficult to determine; no mine map provided to FMI with report. From the written report narrative, estimate between 3800 ft and 13000 ft.
Extent of flame	Report findings show that this was a relatively weak 6 to 7% methane/air explosion, with minor involvement of coal dust. Flame and wind velocities estimated at 50 to 100 ft/sec (150+ ft/sec required to propagate a coal dust explosion per MSHA report). Much of the 003 section was engulfed in flame, and a burned cushion was seen 1100 ft outby.

Extent of forces	Forces developed by the explosion were minimal. In areas where coal dust was a factor, several dry stacked concrete and plaster stoppings were destroyed; however, overpressures of 1 to 2 lb/in.^{2} are all it would take to destroy these, dislodge the top conveyor belt, and move the lid of the power center as was seen (per MSHA conclusions). Bodies were badly burned, but not highly physically damaged.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* NO. Stations would *not* have helped the miners. All miners were found within 150 ft of the ignition source. No miners attempted to use their self-rescuers.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	*FMI assumption:* this was mostly a methane explosion which robbed nearby miners of breathable air, and badly burned them. They were asphyxiated before even attempting to don SCSRs. Miners further out from the blast, however, may have needed a shelter if the contaminated air had propagated further throughout the mine sections.
Total number miners underground at the time of the accident	Fifty-six
Number of miners impacted by the accident versus not impacted	Thirteen impacted; 43 not impacted
Of those miners impacted, number immediately killed	All 13 died very quickly (had traveled outby only about 150 ft)
Of those miners impacted, number that escaped and evacuated	None
Of those miners impacted, number that barricaded	None (no time to barricade)
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All 13 miners would have been neutrally affected because they were only able to travel 150 ft and probably would not have been able to reach a station.

Miners that escaped, escaped within what timeframe?	Report is not specific but all sections of the mine were notified to evacuate very soon after the noon explosion occurred and the evacuation would have progressed quickly. The first rescue team entered the mine about 2:20 pm.
Miners that died, died within what timeframe?	Very quickly because they only traveled about 150 ft (report not specific).
Miners that were rescued, were rescued within what timeframe?	N/A - no miners rescued.

10. Adkins Mining Company, No. 11 Mine (ID No. 15-02290) December 7, 1981; Coal Dust Explosion (8 Fatalities)

First indication of fire, explosion or inundation	12:50 coal dust explosion in face of South Main Section
Death of Miner 1, Miner 2, …., etc.	Blasting from the solid two faces simultaneously resulted in an ignition of suspended coal dust. Methane gas was not a factor. All 8 miners on the section died from injuries, CO poisoning, and smoke inhalation. No evidence of miners attempting to don filter self rescuers.
First knowledge of accident outside mine	Miner outside heard air rush out of mine and saw debris blowing out.
First knowledge of accident elsewhere inside mine	No other miners were underground at the time of the explosion.
Actions and movements of the miners inby (downstream) of fire or explosion.	All eight miners on the section died from injuries, CO poisoning, and smoke inhalation. No attempts to don filter type self rescuers.
Actions and movements of miners (outby) upstream of fire or explosion	No other miners were underground at he time of the explosion
Miners barricade	No attempt to barricade. All eight died almost instantly.
Rescue team enters mine	4:55 barefaced to within several crosscuts of the South Main Section face. Inby they encountered higher levels of CO and donned oxygen.
Rescue team reaches miners	Found 1st victim in last open crosscut at 8:39 pm. Found last of 8 victims at 12:25 am on 12/8/1981.
All miners and rescue team are out of mine	All bodies out of the mine by 2:55 am on 12/08/1981 and all teams out by 3:00 am on 12/8.
Distance of working section from surface of mine	Approximately 2300 ft.
Extent of flame	Flame temperatures in the last open crosscut were estimated to exceed 550°F. Evidence of flame extending outby in one entry 680 ft and 325 ft in another.

Extent of forces	Forces were from a coal dust explosion with no methane involvement. Stoppings were damaged as far as 700 ft outby the explosion. Debris was blown out of the mine with enough force to damage vehicles on the surface.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI Assumption*: NO. All eight miners died from injuries and asphyxiation almost immediately after the explosion. No evidence that victims were able to attempt to don filter type self rescuers.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Eight
Number of miners impacted by the accident versus not impacted	All eight impacted
Of those miners impacted, number immediately killed	All eight killed immediately or very soon after explosion
Of those miners impacted, number that escaped and evacuated	None
Of those miners impacted, number that barricaded	None (no time to barricade)
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Eight would have been neutrally affected because stations were N/A in this situation.
Miners that escaped, escaped within what timeframe?	N/A – None escaped
Miners that died, died within what timeframe?	All eight died immediately or very soon after explosion
Miners that were rescued, were rescued within what timeframe?	N/A – None rescued

11. Mid-Continent Resources, Dutch Creek No. 1 Mine (ID No. 05-00301) April 15, 1981; Explosion (15 Fatalities)

First indication of fire, explosion or inundation	4:08 pm explosion in face of No. 1 entry in Longwall Development Section No. 102.
Death of Miner 1, Miner 2, …., etc.	A coal outburst in the face of No. 1 entry caused an explosive methane mixture in the face. Six miners were trying to dilute the mixture with ventilation when the methane ignited killing all six plus three other miners on the section instantly.
First knowledge of accident outside mine	Immediately after the explosion, gusts of air, dust and debris blew out the portals.
First knowledge of accident elsewhere inside mine	Miner in the Slope entries approximately 3300 ft outby heard "gunshot", were engulfed in dust for 20 sec and had hard hats blown off. Miners further outby felt blast and were engulfed in dust.
Actions and movements of the miners inby (downstream) of fire or explosion.	Six miners in the Slope entries approximately 1700 ft from the source of the explosion were killed almost instantly. All suffered flash burns, but died from CO poisoning. Only one miner in the Slope Section was found wearing his filter type self rescuer. Miners in Section No. 102 died from concussive force, burns, and CO poisoning. None of the miners in Section No. 102 attempted to don self rescuers.
Actions and movements of miners (outby) upstream of fire or explosion	Miners approximately 5700 ft outby the explosion started walking out of the mine and when visibility improved crossed over to the belt entry and rode the conveyor belt to the surface, The miner 3300 ft from the explosion started inby and found three miners in different locations from 2400 to 1900 ft outby the source of the explosion. All three were unconscious with minor burns. Notified outside and stayed with injured until rescue team arrived.
Miners barricade	No attempt to barricade. Rescue teams originally thought miners in Section 102 may have barricaded, but all miners were killed almost immediately.
Rescue team enters mine	5:17 pm 1st team entered under oxygen and brought one uninjured and three injured miners to the surface at 6:39 pm. Other teams started entering at 7:38 pm.
Rescue team reaches miners	Victims located between 10:30 pm on 4/16 and 6:00 am on 4/17/1981.
All miners and rescue team are out of mine	All bodies out of the mine by 7:00 am on 4/17/1981.
Distance of working section from surface of mine	Section No. 102 was approximately 7400 ft and the Slope Section was approximately 6900 ft from the surface.
Extent of flame	Flame extended 1100 ft to the outby end of Section No. 102 and extended 600 ft inby to the face of the Slope entries and outby 700 ft to crosscut 56.

Extent of forces	Force of the explosion destroyed all permanent stoppings outby 1100 ft the entire length of Section No. 102. The section overcast at the mouth of the section was destroyed. All stoppings from 700 ft outby to 600 inby Section No. 102 were destroyed. Damage extended to 1500 ft outby Section No. 102. Injured miners in the Slope entries were knocked down indicating overpressure of at least 2 psi. Pressures near the explosion probably exceeded 15 psi.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* NO – All were killed instantly; only one miner in the Slope Section was found wearing his filter type self rescuer but was unable to try to escape.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption:* YES – Any refuge stations within the 1000 to 2000 ft of the face would have been exposed to forces possibly exceeding 20 psi.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumptions:* viable and easily reachable if miners had survived initial explosions and were able to don self rescuers. A lifeline would have helped guide miners through smoke and dust. First rescue team would have reached the station within 2 hr.
Miscellaneous Comments	*FMI assumption:* the forces generated by this explosion would have likely exceeded the 15 psi force requirement specified by WV for portable chambers within 1000 ft of the face.
Total number miners underground at the time of the accident	Twenty-one
Number of miners impacted by the accident versus not impacted	Assume all 21 were impacted
Of those miners impacted, number immediately killed	Nine killed instantly; six died soon after
Of those miners impacted, number that escaped and evacuated	Two escaped to the surface unassisted while a third uninjured miner stayed in the mine to assist three more miners who were too severely injured to escape; all four were rescued.
Of those miners impacted, number that barricaded	No attempt to barricade
Number of barricaded miners rescued alive	N/A; three injured miners (not in barricade) were rescued alive
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Eighteen would have been neutrally affected. Fifteen miners who died perished too quickly to make it to a station and the three injured survivors were too severely injured to make it to a station.

Miners that escaped, escaped within what timeframe?	The two miners who escaped to the surface arrived there about 4:20 pm, 12 min after the 4:08 pm explosion occurred.
Miners that died, died within what timeframe?	The nine miners on the section were killed instantly; the other six miners who perished in the slope also died almost immediately.
Miners that were rescued, were rescued within what timeframe?	The first rescue team entered the mine at 5:17 pm and the 4 survivors were escorted out by 6:39 pm, 2 hr, 31 min after the 4:08 pm explosion.

12. Westmoreland Coal Co., Ferrell No. 17 Mine (ID No. 46-02493) November 7, 1980; Coal Mine Explosion (5 Fatalities)

First indication of fire, explosion or inundation	Power went out at 3:30 am and some miners noted an air concussion but no one knew it was an explosion (thought it was a roof fall somewhere). By 5:15 am smoke was detected and about 6:00 am the outside was notified and an evacuation order given.
Death of Miner 1, Miner 2, …., etc.	The report assumes immediate death in stating that the five miners were killed at approximately 3:30 am on November 7 as a result of an explosion that occurred in 2 South off the 1 East Main portion of the mine. All miners were found near their workplace having made no obvious attempt to travel or barricade and none of the miners had donned self rescuers.
First knowledge of accident outside mine	About 6:00 am as noted above.
First knowledge of accident elsewhere inside mine	Soon after 6:00 am the full mine was notified to evacuate.
Actions and movements of the miners inby (downstream) of fire or explosion.	N/A – Miners at the site of the explosion were probably killed instantly.
Actions and movements of miners (outby) upstream of fire or explosion	Attempted to determine what had happened after mine power went down – evacuated the mine once it was determined to be an explosion – some miners began investigation into 2 South where they encountered dense smoke and stoppings blown out (then retreated until rescue teams could arrive).
Miners barricade	N/A – Miners at the site of the explosion were probably killed instantly.
Rescue team enters mine	First rescue team entered the mine at 8:45 am.
Rescue team reaches miners	On Novembr 8, between 1:15 am and 2:20 am, all five bodies were found in No. 4 entry of 2 South between No. 26 and 27 crosscuts in the vicinity of the locomotive and rail car. The bodies could not be removed until about 10:25 pm on November 8 because methane buildup in the mine caused an evacuation about 7:00 am earlier that day.

All miners and rescue team are out of mine	Bodies out to the surface at approximately 10:25 pm November 8, 1980. Recovery operations continued after that.
Distance of working section from surface of mine	Not detailed in the report but N/A for this disaster anyway.
Extent of flame	Not discussed.
Extent of forces	Not discussed.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* NO, because the miners were apparently killed instantly. No outby miners were affected and so would not have needed stations.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	Flammable and explosive gasses were allowed to build up in the work area, leading to the explosion.
Total number miners underground at the time of the accident	Report does not indicate total number, but the midnight shift involved only maintenance and no production units were operating. Total was likely only a few more than the five fatalities. [Five was used in our analysis]
Number of miners impacted by the accident versus not impacted	Five were impacted at the workplace of the explosion; all others outby were unaffected.
Of those miners impacted, number immediately killed	All five were immediately killed.
Of those miners impacted, number that escaped and evacuated	None escaped
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No miners that could have been positively, negatively, neutrally affected by stations	Five would have been neutrally affected because they died immediately.
Miners that escaped, escaped within what timeframe?	Report is not specific but miners were notified to evacuate about 6:00 am, 2 hr, 30 min after the explosion. The evacuation would have progressed quickly. The first rescue team entered the mine about 8:45 am.

Miners that died, died within what timeframe?	All five were immediately killed.
Miners that were rescued, were rescued within what timeframe?	None were rescued

13. Kocher Coal Corporation, Porter Tunnel Mine (ID No. 36-01892) March 1, 1977; Water Inundation (9 Fatalities)

First indication of fire, explosion or inundation **Death of Miner 1, Miner 2, …., etc.** **First knowledge of accident outside mine** **First knowledge of accident elsewhere inside mine** **Actions and movements of the miners inby (downstream) of fire or explosion.** **Actions and movements of miners (outby) upstream of fire or explosion** **Miners barricade** **Rescue team enters mine** **Rescue team reaches miners** **All miners and rescue team are out of mine** **Distance of working section from surface of mine** **Extent of flame** **Extent of forces**	The mine was a multi-level anthracite mine in northeastern PA. The West Skidmore South Dip Conveyor Gangway Section accidentally mined into an abandoned mine at 11:50 am on 3/1/1977. Probe holes were being drilled in advance of mining but did not intersect the abandoned mine. The abandoned mine had been developed in the late 1930's and early 1940's and was filled with water. Maps of the old mine were inaccurate. When the miners breached the old mine water rushed in. Survivors said they felt a gust of wind and saw a wall of water. Six miners from the affected section, three with injuries, escaped via the return air emergency escape way to the surface. Sixty five miners in other areas of the mine escaped via intake and return escape ways. Nine miners died in the inundation. The surface of the mine was notified almost immediately. One miner was trapped and subsequently rescued. Mine personnel started reentering the mine almost immediately and helped injured miners to the surface. The first body was found at 2:30 pm and removed to the surface. MESA inspectors started entering the mine by 2:35 pm and by 4:45 pm were exploring the mine trying to locate missing miners. At 5:55 pm on 3/1/1977 rescuers heard tapping from the trapped miner. A 1-3/4 in. hole was drilled through a coal pillar approximately 48 ft to establish communication with the trapped miner. The hole was later expanded so supplies could be provided to him. A rescue tunnel was driven to the trapped miner and he was rescued on 8:05 pm on 3/6/1977, reaching the surface at 8:35 pm. Recovery efforts continued until 12:35 pm on 3/30/1977 with the last body removed by 1:45 am on 3/31/1977.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Stations would not have helped unless they were built to resist significant hydraulic overpressure.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A

If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	It is not clear that a refuge station is a practical solution to protecting against inundation.
Total number miners underground at the time of the accident	Report does not provide this number but a figure of 81 can be calculated via the account.
Number of miners impacted by the accident versus not impacted	Sixteen impacted and 65 not directly impacted
Of those miners impacted, number immediately killed	Times of death are unknown but would have been soon after the inundation
Of those miners impacted, number that escaped and evacuated	Six (escaped on their own to the surface
Of those miners impacted, number that barricaded	None barricaded, though one was trapped and found a safe place to await rescue
Number of barricaded miners rescued alive	One was rescued after 5 days.
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All 16 affected miners would have been neutrally affected assuming a station would not be suitable to protect against inundation.
Miners that escaped, escaped within what timeframe?	Report is not specific; evacuation began immediately and would have concluded fairly quickly. The first body was found during recovery at 2:30 pm, 2 hr 40 min after the 11:50 am inundation.
Miners that died, died within what timeframe?	Times of death are unknown but would have been soon after the inundation
Miners that were rescued, were rescued within what timeframe?	Sole trapped miner was rescued at 8 am March 6, almost five full days after the inundation

14. Scotia Coal Company, Scotia Mine (ID No. 15-02055) March 9 and 11, 1976; 2 explosions (26 Fatalities)

First indication of fire, explosion or inundation	The first explosion occurred about 11:45 am on 3/09/1976 in the 2 Southeast Main Section. An outby supervisor called outside to report the explosion soon after it occurred. The second explosion occurred at 11:30 pm on 3/11/1976 and was reported after two surviving miners traveled out of the section and called it in.

Death of Miner 1, Miner 2, …., etc.	The report is not specific. First explosion: all 15 miners in the sections died as a result of the explosion. Four miners in the 2 Southeast Main section and five in 2 Left were killed instantly while six other miners in 2 Left Section died after a potentially significant period of time (several hours?) because they attempted to barricade. Second explosion: 11 miners were killed instantly and two miners escaped.
First knowledge of accident outside mine	Both explosions: survivors inside the mine reported the explosions to the surface as soon as they could reach phones (times not specified but presumably in minutes).
First knowledge of accident elsewhere inside mine	Report not specific but presumably very soon after the explosions were reported to the surface.
Actions and movements of the miners inby (downstream) of fire or explosion.	First explosion: nine miners in the 2 Southeast Main and 2 Left sections were killed instantly while six of the 11 miners in 2 Left Section apparently tried to barricade. Second explosion: 11 miners during recovery operations were killed instantly.
Actions and movements of miners (outby) upstream of fire or explosion	First explosion: a supervisor outby the explosion survived and called the surface. Ninety other miners working in other areas of the mine evacuated to the surface.
Miners barricade	Six miners attempted to barricade (time unknown).
Rescue team enters mine	Rescue teams entered the mine at 4:30 pm and reached the barricade approximately 10 1/2 hr after the explosion.
Rescue team reaches miners	Rescue teams reached the barricade approximately 10 1/2 hr after the explosion. The final two bodies were found at 1:20 am on 3/10/ 1976 about 13 1/2 hr after the explosion.
All miners and rescue team are out of mine	First explosion: the rescue teams had recovered all bodies after about 18 hr. Second explosion: rescue teams found the 11 bodies about 12 hr after the explosion but could not recover them due to hazardous conditions. The mine was sealed and reopened about a year later.
Distance of working section from surface of mine	Unknown without more detailed information, maps, etc.
Extent of flame	Report does not distinguish flame versus forces and discusses an "explosion area" (see below).

Extent of forces	The area of the first explosion extended throughout the section, extended into 2 Left Section, and dissipated as they reached the Northeast main junction. The area of the second explosion were much more extensive and extended throughout 2 Left, 2 Southeast Mains and throughout a significant portion of the Northeast Mains.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption*: YES – Refuge stations would have likely saved at least six of the miners who survived the first explosion. The 11 fatalities of the second explosion would not have been helped by a station. The two escaping miners may have used a station if available. Their escape covered a few thousand feet (exact distance could not be determined from the report) through thick dust and smoke using the phone line for guidance.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption*: YES – Stations would have been exposed to limited forces and flame from the first explosion in the 2 Left Section and significant forces and flame in the Southeast Main Section. The second explosion was much larger than the first and any stations at currently required locations would have had to be explosion proof and flame resistant.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumption*: placement guidelines would have been acceptable.
Miscellaneous Comments	None
Total number miners underground at the time of the accident	First explosion: 106 Second explosion: 13
Number of miners impacted by the accident versus not impacted	First explosion: 16 were directly impacted; 90 were not directly impacted. Second explosion: all 13 were impacted.
Of those miners impacted, number immediately killed	First explosion: 9 Second explosion: 11
Of those miners impacted, number that escaped and evacuated	First explosion: 1 Second explosion: 2
Of those miners impacted, number that barricaded	First explosion: 6 Second explosion: None
Number of barricaded miners rescued alive	First explosion: None Second explosion: N/A
Number of barricaded miners that died	First explosion: 6 Second explosion: N/A
No. miners that could have been positively, negatively, neutrally affected by stations	First explosion: the six who barricaded would have been positively affected. Second explosion: The 11 were killed instantly and two escaped would be neutrally impacted.

Miners that escaped, escaped within what timeframe?	Report does not say – presumably the one survivor and 90 other miners in the mine escaped to the surface as quickly as possible after the first explosion occurred. The two survivors of the second explosion were also likely out of the mine fairly soon after the explosion.
Miners that died, died within what timeframe?	First explosion: Nine immediately and 6 after possibly several hours Second explosion: all 11 immediately
Miners that were rescued, were rescued within what timeframe?	N/A – No miners were rescued alive

15. Itmann Coal Co., Itmann No. 3 Mine (ID No. 46-01576) December 16, 1972; (5 Fatalities)

First indication of fire, explosion or inundation	Methane explosion occurred 1000 ft outby No. 4 longwall panel face about 3:45 pm during shift change, December 16 but mine personnel were not aware of it until crew failed to arrive on surface and personnel entered 4 panel section to investigate; USBM was called at 4:55 pm.
Death of Miner 1, Miner 2, …., etc.	Five of the 8-man crew were killed and three were burned severely. Presumably, the five deceased were killed instantly or soon thereafter (report not specific).
First knowledge of accident outside mine	Sometime within about 1 hr after the explosion occurred.
First knowledge of accident elsewhere inside mine	All personnel elsewhere within the mine were not aware of the explosion.
Actions and movements of the miners inby (downstream) of fire or explosion.	All men were in a portal bus enroute to the surface when the trolley ignited a methane pocket. One miner (Billings) crawled about 200 ft inby, realized his wrong direction, turned around, passed the portal bus and kept going outby until he lost consciousness. Another miner (Mullens) crawled out of the bus, but lost consciousness within seconds. A third miner (Bailey) jumped out, crawled inby, turned around, passed the bus, found a route into No. 2 intake entry and crawled outby until he lost consciousness. A fourth miner (McMillion) survived the explosion, but was too injured to be helped by the others and he died in-place.
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	Note that only one miner (Bailey) was able to don and use his self rescuer. Billings couldn't open his up (probably due to extend of burn injuries) and Mullens lost consciousness too quickly. Bailey and Billings both attempted to evacuate, but lost consciousness enroute. No barricading was attempted.
Rescue team enters mine	Mine personnel began investigating and establishing ventilation immediately (starting about 5:00?). Mine rescue team arrived on section about 7:45 pm.
Rescue team reaches miners	Rescue team found Bailey at 8:00 pm alive but unconscious. All others found by 8:30 pm.

All miners and rescue team are out of mine	Bailey out of mine at 8:42 pm. Billings and Mullens out of mine at 9:24 pm. Five deceased miners out of mine by 11:30 pm
Distance of working section from surface of mine	Working faces to mouth of section was about 4,800 ft; distance from explosion to mouth of section about 3,800 ft; distance from mouth of section to surface unknown (can't determine without mine map).
Extent of flame	Flame evidence was minimal. Tests indicated that headgear of one victim was subjected to >190 deg but <450 deg heat. Flame extended about 650 ft inby and outby portal bus in No. 1 entry and lesser distances in adjacent No. 2 entry.
Extent of forces	Forces estimated to extend about 1000 ft inby and outby portal bus in all three entries of panel and were dissipated within 4 panel section. Personnel in 5 panel section about 4000 ft away felt only slight air reversal. Generally, the explosion was considered to be relatively weak.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumptions*: YES – Due to weak explosion, The stations would have helped regarding survival of men and movement of men. With newer SCSRs, men might have stayed conscious and been able to crawl to a station nearby the section. The extent of their injuries would have likely made it impossible to crawl to the surface or even to the section mouth.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption*: NO – Stations would *not* have needed to be explosion-proof given relatively minor forces and obvious survival of men in those forces.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumptions*: placement per guidelines would have been OK. Survivors attempted to travel outby and a lifeline from the portal bus guiding them to a station between No. 1 and 2 entries would have aided the miners.
Miscellaneous Comments	None
Total number miners underground at the time of the accident	One hundred twenty-one
Number of miners impacted by the accident versus not impacted	Eight impacted; 113 not impacted
Of those miners impacted, number immediately killed	Five
Of those miners impacted, number that escaped and evacuated	Three attempted to escape but fell unconscious
Of those miners impacted, number that barricaded	None attempted
Number of barricaded miners rescued alive	Three unconscious miners were rescued – they had not barricaded

Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Three miners could have been positively affected by a station; five miners would have been neutrally affected (died instantly or succumbed to serious injury).
Miners that escaped, escaped within what timeframe?	N/A – No miner successfully escaped.
Miners that died, died within what timeframe?	Died instantly.
Miners that were rescued, were rescued within what timeframe?	The three unconscious miners were rescued within about 4 hr, 45 min.

16. Consolidation Coal Company, Blacksville No. 1 Mine (ID No. 46-01867) July 22, 1972; Coal Mine Fire (9 Fatalities)

NOTE: The report provided by MSHA-Beckley is the Final Report that supplements an earlier preliminary report. The final report contains a summary of the disaster and details the recovery of the mine after being sealed for more than 5 months. The preliminary report, referenced as being provided in an Appendix 1, may contain more details on the disaster itself. The Appendix 1 was not included with the report version provided to us by MSHA-Beckley. The assessment below was made using only the level of detail provided in the Final Report.

First indication of fire, explosion or inundation	Fire started about 7:30 pm July 22, 1972 along 3 North track between A-1 and A-2 sections when machinery contacted energized trolley wires. Presumably men involved in movement of machinery on track knew of the fire immediately.
Death of Miner 1, Miner 2, …., etc.	The report does not speculate on timelines of deaths because the investigation could not be continued for about 5 months after the disaster. Facts indicate that fire burned for 45 min before smoke was detected on A-2 section and more than 60 min before it was detected on A-3 section. A-2 was contacted about the fire at about 8:00 pm and A-3 was contacted about 8:30 pm. The miners on the sections delayed a considerable time before leaving their sections (report does not speculate on when). By the time they were attempting to escape, the fire had already destroyed the integrity of the escape system and the report implies that due to this delay, escape became impossible.
First knowledge of accident outside mine	The report does not say exactly when the fire was reported to the outside. *FMI assumption*: since the A-2 section was notified about 8:00 pm, and the fire started about 7:30, the miners involved in the fire's origination likely called the fire to the outside sometime between 7:30 and 8:00 pm.
First knowledge of accident elsewhere inside mine	Not sure from report but probably irrelevant to activities on the A-2 and A-3 sections because all miners in the mine (except those in A-2 and A-3) escaped without incident.

Actions and movements of the miners inby (downstream) of fire or explosion.	Miners in A-2 and A-3 sections were located 2,200 and 3,600 inby the fire's origin respectively. As noted above, they took no action to evacuate their sections for a considerable time after the start of the fire and the report does not speculate on when they finally decided the situation was dire enough to need to escape. By the time they did try to escape, however, the integrity of the escape ways was destroyed. During recovery months after the fire, 4 bodies were found in the 3 North Mains very close to the junction with the A-2 section. Presumably, the miners (all of whom were wearing self-rescuers) had traveled the escape way from the A-3 section to this point. Five bodies were discovered within the A-2 section along the belt entry. Some were covered by fallen top coal. The report did not mention self-rescuer use for these 5 miners. These miners also were presumably attempting to escape the mine.
Actions and movements of miners (outby) upstream of fire or explosion	The report provides little detail about the activities of outby/upstream miners. All miners except those in A-2 and A-3 escaped OK and presumably some miners began fire control, though unsuccessfully.
Miners barricade	The victims were finally reached during recovery efforts 5 months after the disaster and no evidence was found of barricading efforts.
Rescue team enters mine	It was over 4 hr after the fire began that rescue teams went underground to fight the fire and over 5 hr before actual rescue attempts were made to reach the nine trapped miners. It is not clear whether these time delays contributed to the deaths of the miners.
Rescue team reaches miners	Fire fighting and rescue efforts to reach the trapped miners failed and by the afternoon of July 24 (almost 2 days after the start of the fire), methane in the returns built up to the point where the call was made to evacuate the mine. At 2:45 pm July 24, as the miners were leaving the mine, an explosion occurred. A decision was made to seal the mine and recovery didn't restart until January 3, 1973 (over 5 months later). The 9 bodies were found and recovered on January 3 and 4, 1973 and all were out of the mine by 7:50 pm January 4, 1973.
All miners and rescue team are out of mine	See above.
Distance of working section from surface of mine	Approximately 14,000 ft to the portal shaft (estimated from very little information in the report and no clear mine maps to refer to).
Extent of flame	Very little detail provided, though the report states that "the only area evidencing effects from fire and flame, other than the area immediately surrounding the origin of the fire, was in the A-2 section". This was based on the burned condition of bodies and materials.

Extent of forces	Forces were not relevant regarding the original fire, but were relevant to the explosion that occurred on July 24. The report simply states that the explosion occurred in the 3 North Mains inby the fire area and its forces destroyed all ventilation controls. Information is not available to relate forces to the locations where miners were found or to places where rescue stations might have been located had they been provided in the mine.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumptions:* YES – A station would have been viable if the miners reached a sealed, explosion proof station with at least 96 hr of breathable air supply, or an air supply through a borehole to the surface. Assuming the exact location of the station pre-surveyed and mapped, the miners could have been rescued through a drilled escape shaft from the surface to the station.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption:* YES – Per the scenario discussed above, the station would have needed to be explosion-proof to resist the forces of the methane explosion that occurred after the fire started and rescuers were forced from the mine.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumption:* per the scenario discussed above, if stations had been provided, placement according to guidelines should have been OK.
Miscellaneous Comments	The problem in this case was that the miners waited a long time to begin their escape. Because of the delay, it was not possible for rescuers to reach the miners from within the mine because the fire was not brought into control and conditions worsened to the point where rescue efforts had to be abandoned and the mine had to be sealed.
Total number miners underground at the time of the accident	Forty-three miners
Number of miners impacted by the accident versus not impacted	Nine were impacted and 34 were not impacted
Of those miners impacted, number immediately killed	None were killed immediately; all nine killed delayed a considerable time before deciding to try to escape (report is not specific)
Of those miners impacted, number that escaped and evacuated	None successfully escaped
Of those miners impacted, number that barricaded	None attempted to barricade
Number of barricaded miners rescued alive	None were rescued alive.
Number of barricaded miners that died	All nine miners killed died attempting to escape (none barricaded)

No. miners that could have been positively, negatively, neutrally affected by stations	All nine miners would have been positively affected by a station (assuming a borehole rescue was viable).
Miners that escaped, escaped within what timeframe?	The report does not give a timeline. It was 4 hr after the start of the fire before rescue teams were ready to enter the mine and 5 hr before actual rescue efforts were begun. Presumably all evacuated miners were out of the mine well before rescue efforts began.
Miners that died, died within what timeframe?	The report does not give a timeline. All affected miners took no action to evacuate their sections for a considerable time after the start of the fire and the report does not speculate on when they finally decided the situation was dire enough to need to escape
Miners that were rescued, were rescued within what timeframe?	None were rescued alive

17. Finley Coal Co., No. 15 and 16 Mines (ID No. 15-02593) December 30, 1970; Coal Dust Explosion (38 Fatalities)

First indication of fire, explosion or inundation	Coal dust explosion occurred at 12:20 pm December 30 about 120 ft inby the mouth of No. 1 entry, 2 left, No. 16 Mine at a site being prepared for a new belt tail piece.
Death of Miner 1, Miner 2, …., etc.	Thirty three TOTAL killed instantly; five more a short time later: 19 killed instantly in No. 15 Mine and two died later; 14 killed instantly in No. 16 Mine and three died later. Note that these two mines were interconnected. Blasting with non-permissible explosives and prima cord resulted in an ignition of suspended coal dust. Methane gas was not a factor.
First knowledge of accident outside mine	Unknown; MSHA on scene before 3:00 pm. Debris blew out of the mine almost immediately.
First knowledge of accident elsewhere inside mine	N/A – All miners in mine affected. There was only one other miner underground near the portal. He was slightly injured by concussive force and flying debris.
Actions and movements of the miners inby (downstream) of fire or explosion.	Three miners in 16 Mine moved less than 100 ft from their work area. Two miners in 15 Mine (loading machine operator and mechanic) were found about 140 ft from their machine. These five did not appear to have been killed instantly by the explosion. The other 33 miners were killed instantly. None of the miners had access to self rescuers. The self rescuers for No. 16 Mine were 400 ft outby. Sixteen self rescuers for No. 15 Mine were stored outside. The five miners who did not die instantly apparently died from smoke inhalation and CO poisoning. No autopsy data available.
Actions and movements of miners (outby) upstream of fire or explosion	One miner was outby very near the mine portal in the belt entry and was slightly injured by the explosion force and flying debris. He exited the mine immediately.

Miners barricade	No attempt to barricade. *FMI assumption*: 5 miners survived the explosion for a time but did not carry self-rescuers. If they had, it *may* be possible that they could have escaped to the surface or made it to a station, though it's unclear without access to the report maps to determine whether the extent of flame and/or forces would have killed them first.
Rescue team enters mine	Rescue personnel from the Bureau of Mines and State entered No. 15 Mine at 3:00 pm on 12/30 and No. 16 Mine at 4:30 pm on 12/30/1970.
Rescue team reaches miners	15 Mine: Three bodies found in mains at crosscut 29/30 after 3:00 pm, December 30 before crews had to retreat due to gasses. 16 Mine: One body found at section mouth at 7:00 pm, December 30 + 14 others further inby.
All miners and rescue team are out of mine	Three miners in Mine 16 removed at 8:00 pm, December 30 All bodies were out of both mines by 10:00 am, December 31.
Distance of working section from surface of mine	No. 15 Mine approximately 2650 ft. No. 16 Mine approximately 3300 ft.
Extent of flame	Mine map unavailable but verbal discussion states that flame extended over the major part of both Mines 15 and 16 outby to within 500 ft of the portal. It did not extend into the first right section of Mine 15.
Extent of forces	Mine map unavailable but verbal discussion states that forces started from the point of origin in No. 1 entry, 2 Left, No. 16 mine and propagated to the surface. However, the forces expanded rapidly and became less intense as they traveled toward the surface. Stopping damage was extensive. The report contains no calculations of force values.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption*: It is possible that a station could have helped if the five miners surviving the explosion had access to self rescuers. We were unable to determine the extent of flame and forces, it is unknown whether the miners would have survived to don self rescuers and make it to a station. Continuing issue: Seam height was only 29 to 36 in.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	Unknown; mine map not available for details of flame and forces and estimates of forces not provided. *FMI assumption*: any stations within 1000 to 2000 ft would have experienced significant overpressure and would have to be explosion proof. This is based the extent of observed stopping damage from the explosion. Extent of flame would dictate that any station be fire resistant.

If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	*FMI assumption*: YES – It is possible the station would have needed to be closer than 1000 to 2000 ft. given the conditions in the mine and the extent of injuries to the surviving miners. Seam height was a contributing problem. No commercially available stations are viable. Supply storage and movement would be a challenge. In this height, miners crawl on their hands and knees. The injured miners only traveled 100 to 140 ft after the explosion. The distance may have been much greater if they could have walked.
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Thirty-nine
Number of miners impacted by the accident versus not impacted	All 39 impacted
Of those miners impacted, number immediately killed	Thirty-eight: 33 instantly and five some time later
Of those miners impacted, number that escaped and evacuated	One miner outby near the mine portal
Of those miners impacted, number that barricaded	None (all killed instantly or shortly after explosion except one outby miner who escaped)
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Five miners could have been positively affected by a station if it had been located quite close to the section; 33 miners would have been neutrally affected (died instantly). One survivor escaped (neutrally affected).
Miners that escaped, escaped within what timeframe?	The one outby miner exited the mine immediately
Miners that died, died within what timeframe?	33 died instantly and 5 others died some time later (presumably a fairly short time later, well before rescuers could reach them)
Miners that were rescued, were rescued within what timeframe?	N/A

Disasters from 1970 to 2006 involving fatalities in which less than five miners were killed:

18. R&D Coal Company, Inc. Mine, R&D Coal Company, Inc. (ID No. 36-02053) October 23, 2006; Fatal Methane Explosion (1 Fatality)

First indication of fire, explosion or inundation	10:00 am October 23, 2006.
Death of Miner 1, Miner 2, …., etc.	Report is not specific (assume victim was killed instantly).
First knowledge of accident outside mine	Report is not specific. A call was made to 911 at 11:09 am, so the accident was called out to the outside some time before 11:09 am.
First knowledge of accident elsewhere inside mine	Most or all miners in the mine noticed unusual forces during routine blasting (a more powerful and loud 3rd blast) and knew something was wrong).
Actions and movements of the miners inby (downstream) of fire or explosion.	Blasts and explosion were at the face - no miners downstream.
Actions and movements of miners (outby) upstream of fire or explosion	Traveled to the area of the accident to investigate what happened and attempted to help victim.
Miners barricade	No attempt to barricade.
Rescue team enters mine	Arrived on site at about 11:30 am and enter mine some time after that.
Rescue team reaches miners	Report is not specific on arrival of rescue team underground.
All miners and rescue team are out of mine	The victim was removed to the surface about 12:45 pm.
Distance of working section from surface of mine	6,120 ft
Extent of flame	Details not available without mine maps. Quoted from the MSHA report: "The temporary stoppings from the monkey airway to the No. 5 miner heading were blown out. Line curtain and tubing extending from No. 5 to the face was damaged or destroyed. The air fan, located outby the No. 5 miner heading, was found in the No. 19 chute a distance of approximately 470 ft. Line brattice was melted from approximately 30 to 75 ft outby the face."
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption*: NO – One miner was killed, presumably instantly; others could have escaped without injury.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A

Miscellaneous Comments	None
Total number miners underground at the time of the accident	Seven
Number of miners impacted by the accident versus not impacted	Two were impacted and the other five were not directly impacted.
Of those miners impacted, number immediately killed	One
Of those miners impacted, number that escaped and evacuated	One of the two miners directly impacted survived without injury; escape and evacuation was not necessary
Of those miners impacted, number that barricaded	N/A – Barricading was not necessary
Number of barricaded miners rescued alive	N/A – No miners barricaded and none required rescue
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All seven miners in the mine were neutrally affected.
Miners that escaped, escaped within what timeframe?	N/A – Escape was not required
Miners that died, died within what timeframe?	Report is not specific (assume the one victim was killed instantly)
Miners that were rescued, were rescued within what timeframe?	N/A

19. Aracoma Coal Co., Inc, Alma Mine No. 1 (Mine ID No. 46-08801) January 19, 2006; Belt Fire (2 Fatalities)

First indication of fire, explosion or inundation	5:14 pm on 1/29/06 the No. 9 headgate longwall belt storage unit caught fire. Indications are the fire actually started earlier around 5:05 pm but the AMS system started alarming for CO at this time.
Death of Miner 1, Miner 2, …., etc.	The two miners died during their attempted escape from the No. 2 Section.
First knowledge of accident outside mine	5:14 pm on 1/19/2006 when the CO alarm of the AMS when off on the surface. Operator, who was in charge of monitoring the system, did not alert miners underground for another 28 min.
First knowledge of accident elsewhere inside mine	Miners in the vicinity of the fire saw smoke 10 min before the AMS alarmed and were attempting to fight the fire. Miners in No. 2 Section were not notified by the AMS operator until 28 min after the alarm first sounded. The No. 9 Longwall crew was aware of a potential problem at 5:05 pm but was never notified by the AMS operator of the alarm at 5:14 pm. They decided to evacuate at approximately 5:50 when they lost phone contact.

Actions and movements of the miners inby (downstream) of fire or explosion.	At approximately 5:42 pm the No. 2 Section was notified that there was a fire at the No. 9 Longwall headgate belt take-up storage unit and that there was smoke in the intake. The Section foreman and 11 other miners boarded a rubber-tired diesel vehicle and started driving out the intake travel way. 1800 ft outby they smelled smoke. At 2200 ft they encountered light smoke. At this point the roadway turned right into an adjacent intake entry. Here they encountered dense smoke. Several miners immediately donned SCSRs while other traveled outby another 100 to 225 ft before donning. The miners traveled on foot through dense smoke by feeling along the rib and holding unto each other for a few hundred feet to a mandoor. The mandoor gave them access to the belt entry, which was clear of smoke. At this point they discovered the two victims missing (they had become separated from the crew in the dense smoke). Several miners reentered the smoke in an unsuccessful attempt to find the missing miners. The survivors continued their evacuation for another 1900 ft until they were outby the No. 9 Longwall headgate belt drive and then reentered the primary escape way. They then joined other miners fighting the fire until ordered to evacuate at 9:30 pm. Out of mine at 10:30 pm.
Actions and movements of miners (outby) upstream of fire or explosion	Miners and supervisors in the vicinity of the fire attempted to extinguish the fire until ordered to evacuate at 9:30 pm on 1/19/2006. At 6:00 pm on 1/19/2006 miners on the No. 9 longwall face started evacuation by walking out the intake. They returned to the face to get SCSRs and curtain to fight the fire. They stayed underground assisting in fire fighting until ordered to evacuate the mine at 9:30 pm. All miners outside by 10:30 pm.
Miners barricade	No attempt to barricade.
Rescue team enters mine	11:30 pm on 1/19/2006. One team explored for victims; the second attempted to extinguish the fire.
Rescue team reaches miners	Reached first victim at 2:40 pm and second victim at 3:20 pm on 1/21/2006.
All miners and rescue team are out of mine	Two bodies out of the mine by sometime after 3:20 pm on 1/29/2006. Rescue teams continued to fight the fire until it was extinguished on 1/24/2006.
Distance of working section from surface of mine	Not known. Miners traveled at least 4700 ft during the escape There is a shaft in the vicinity.
Extent of flame	Flame was limited to area around the No. 9 Headgate belt take-up storage unit.
Extent of forces	There were no forces. Belt fire only. No gas or dust explosion.

Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* Yes – However, refuge stations within 1000 ft of the face as required by WV may not have been useful in this case. Miners did not encounter smoke until they were outby another 1200 ft and were not aware until then that the primary escape way had smoke. Breathable air, as required by MSHA, would have been within a couple hundred feet of where smoke was first encountered. A station near or at breathable air would likely have positively affected the outcome.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	*FMI assumption*: NO – Any refuge stations within the 1000 to 2000 ft of the face, would not have experienced any forces. This was a belt fire with no gas or coal dust explosion.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	Viable and easily reachable. The miners traveled 2200 ft on a mantrip before encountering light smoke. At that point the roadway went through a crosscut into heavy smoke. Miners donned self rescuers and proceeded on foot to a mandoor leading to the beltway (secondary escape way). Several miners donned right away; others traveled in smoke up to 225 ft before donning. The two miners who died became separated from the surviving miners. Miners traveled outby in the belt entry in clear air for another 1900 ft and then reentered the primary escape way. Total distance traveled during the escape was approximately 4700 ft. Lifelines would have helped guide miners through the smoke to the mandoor or to a station outby more than 2000 ft. Any station outby 2000 ft or less would have been reachable in light smoke. Rescue teams could have reached miners quickly after changing ventilation to prevent smoke from entering the intake entries.
Miscellaneous Comments	This is a good example of how refuge stations may have saved two miners' lives.
Total number miners underground at the time of the accident	Twenty-nine; 12 in No. 2 Section + seven on the longwall + 10 outby.
Number of miners impacted by the accident versus not impacted	Assume all 29 were impacted; apparently only the 12 on No. 2 Section were subjected to a tenuous escape (and two were killed)
Of those miners impacted, number immediately killed	None immediately killed; two killed trying to escape
Of those miners impacted, number that escaped and evacuated	Twenty-seven escaped and evacuated
Of those miners impacted, number that barricaded	None barricaded
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A

No. miners that could have been positively, negatively, neutrally affected by stations	Twenty-seven were neutrally affected because they escaped successfully; two could have been positively affected because they could have made it to a station after being separated from the others. *Alternate scenario*: all 12 could have entered the station and waited for rescue which would have readily arrived. 10 neutrally affected; two positively affected. No change for other 15 who escaped (neutral).
Miners that escaped, escaped within what timeframe?	The report is not specific. The fire probably started about 5:05 pm and the first CO alarm went off at 5:14. Finally at 5:42 pm miners in No. 2 Section were told to evacuate. Miners in the longwall began evacuation about 6:00. All miners except the two that died would have made it to safety sometime after 6:00 pm.
Miners that died, died within what timeframe?	Not known (probably sometime before or after 6:00 pm, or more or less than an hour after the fire started).
Miners that were rescued, were rescued within what timeframe?	N/A

20. Plateau Mining Corp., Willow Creek Mine, (ID No. 42-02113) July 31 and August 1, 2000; 4 Explosions (2 Fatalities)

First indication of fire, explosion or inundation	11:48 pm 1st explosion on D-3 Longwall face near headgate; 2nd explosion occurred at 11:55 pm, a third at 11:56 pm, and a fourth at 12:17 am on 8/01/2000.
Death of Miner 1, Miner 2, …., etc.	A roof fall behind the shields ignited methane behind the shields and ignited liquid hydrocarbon behind the shields that comes from surrounding strata during mining. The resulting fire ignited explosions 2 to 4. The first explosion caused minor injuries to miners in the headgate area. Miners started fighting fire with water hoses and fire extinguishers. Miners also secured additional fire extinguishers and prepared to evacuate the section. The second and third explosions, which occurred approximately 1 min apart, caused two fatalities and significant injuries to 5 other miners that were still on the section after the first explosion. Three of the injured miners evacuated, two injured could not evacuate. A fourth explosion occurred at 12:17 am on 8/1/2000. None of the miners still on the section sensed the 4th explosion.
First knowledge of accident outside mine	The first explosion caused loss of signal from AMS sensors in D-3 Longwall. The outside was notified of fire and ordered evacuation of continuous miner sections.

First knowledge of accident elsewhere inside mine	Miners elsewhere in the mine were alerted to evacuate by PAD (personal Emergency Devices) by surface personnel after first explosion. Miners on the face felt minor pressure from the first explosion. Miners in the headgate felt overpressure but thought it was from a roof fall in the gob. Second and third explosions caused significant damage, injuries and deaths. Air near face had significant dust.
Actions and movements of the miners inby (downstream) of fire or explosion.	Two of the miners evacuated after the second explosion, one in a truck and one on foot following a water line through dust. Two injured miners donned SCSRs; one could not open his SCSR. Three miners boarded the mantrip and drove out of the mine. Two miners' injuries prevented evacuation. Two other miners died from injuries from the second explosion.
Actions and movements of miners (outby) upstream of fire or explosion	Several miners traveled to the mouth of the longwall but were ordered to evacuate before entering the section. They reached the surface by 12:45 am on 8/01. Other miners were notified by Pads and evacuated after the first explosion.
Miners barricade	No attempt to barricade.
Rescue team enters mine	2:00 am on 8/01/2000.
Rescue team reaches miners	Found two surviving injured miners and two fatalities and returned to the surface by 4:00 am on 8/01/2000.
All miners and rescue team are out of mine	4:00 am on 8/01/2000. Mine openings sealed at 10:30 am on 8/01/2000.
Distance of working section from surface of mine	Likely several thousand feet to the portal. The D-3 longwall panel was 4200 ft long and 815 ft wide. It had only retreated 250 ft so the face was approximately 3900 ft from the mouth of the section.
Extent of flame	Only a small amount of methane was involved in the first explosion and flame spread was limited. While the 2nd and 3rd explosions were larger and more powerful, flame spread was limited to the headgate area and face of the longwall. Several injured miners suffered burns.
Extent of forces	Force of first explosion was estimated to be 5 psi near the explosion, 1 to 2 psi in the headgate and approximately 0.5 psi across the face. Forces damaged regulators outby in the headgate. The actual forces from the 2nd and third explosions were estimated to be less than the first but miners were closer than they were during the first explosion causing more serious injuries. Miners were thrown through the air causing blunt force injuries and deaths.

Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	*FMI assumption:* NO - Two miners did not survive the 2nd explosion and died from blunt trauma. Five miners who survived the explosion were able to evacuate the panel. Two of the injured miners were rescued by rescue teams. It is doubtful that they could have traveled any reasonable distance to reach a station. Injuries prevented them from even entering the mantrip for evacuations.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	The report does not provide this information.
Number of miners impacted by the accident versus not impacted	The report does not provide this information; attempts to determine this from names and narrative in the report indicated about 9 miners in the D-3 longwall section.
Of those miners impacted, number immediately killed	Two killed immediately after the 2nd or 3rd explosions
Of those miners impacted, number that escaped and evacuated	Five evacuated
Of those miners impacted, number that barricaded	None attempted to barricade (those able made it out to safety)
Number of barricaded miners rescued alive	N/A – None barricaded, though two miners on the longwall section too injured to escape were rescued.
Number of barricaded miners that died	N/A – None barricaded
No. miners that could have been positively, negatively, neutrally affected by stations	Nine neutrally affected because five were able to escape without the need for a station, two were too injured to make it to a station and two others were killed instantly
Miners that escaped, escaped within what timeframe?	Miners escaped at various times, arriving at the surface at 12:12 am, 12:45 am and 1:30 am on 8-1, from 24 min to 1 hr 42 min after the first explosion of 11:48 pm on 7-31.
Miners that died, died within what timeframe?	Two killed immediately after the 2nd or 3rd explosions
Miners that were rescued, were rescued within what timeframe?	Two rescued miners were out of the mine by 4:00 am on 8-1, about 4 hr 12 min after the first explosion

21. A. A. & W Coals Inc., Elmo No. 5 Mine, Kentucky (ID No. 15-16856) November 30, 1993; Explosion (1 Fatality)

First indication of fire, explosion or inundation	1:20 pm, November 30th.
Death of Miner 1, Miner 2, …., etc.	Death of single victim occurred within minutes of explosion by asphyxiation.
First knowledge of accident outside mine	Immediately; people on surface observed dust cloud
First knowledge of accident elsewhere inside mine	Immediately – They felt it.
Actions and movements of the miners inby (downstream) of fire or explosion.	No activity inby explosion.
Actions and movements of miners (outby) upstream of fire or explosion	Miner 1, scoop driver, died at explosion point when he ignited the methane and coal dust with a cigarette lighter in old mine workings. All other miners were a considerable distance away at the working section, some at the power station (one injured by blast), and one at the charging station. They gathered together, and prepared SCSRs but didn't need them. They could have left the mine, but stayed to help fix the ventilation flow. Two miners proceeded to start the search for the victim, but were instructed to evacuate mine prior to rescue teams being sent in.
Miners barricade	No barricade
Rescue team enters mine	Approximately 6 pm
Rescue team reaches miners	Between approximately 10 am and 11:30 am, December 2nd
All miners and rescue team are out of mine	Approximately 12 pm, December 2nd
Distance of working section from surface of mine	Approximately 6700 ft
Extent of flame	Flame extent was within 75 ft of the ignition point (a cigarette lighter). Methane and coal dust ignited.
Extent of forces	Estimated at 2 to 4 psi
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Stations would not have helped here. A miner lighting a cigarette in a mined out area that had built up methane levels caused the explosion. He died from CO poisoning and smoke inhalation, which would have occurred immediately after the blast. Other miners did not require breathable air to survive and evacuated without impediment.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A

If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Seventeen
Number of miners impacted by the accident versus not impacted	Two impacted, 15 not impacted
Of those miners impacted, number immediately killed	One asphyxiated within minutes
Of those miners impacted, number that escaped and evacuated	One
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	The miner that died would have been neutrally affected (asphyxiation occurred too fast). One miner escaped successfully (neutral). The other miners did not have noxious air or an impediment to escape where they were, so all were neutrally affected.
Miners that escaped, escaped within what timeframe?	Miners did not attempt to leave the mine immediately. Instead, they gathered and made attempts at ventilation control, but could have left immediately without impediment.
Miners that died, died within what timeframe?	Within a few minutes (of asphyxiation).
Miners that were rescued, were rescued within what timeframe?	The rescue team did not reach the one miner missing until approximately 46 hr after event, since boreholes were drilled to establish whether or not a fire existed. He was dead when they found him, but had probably died within minutes of the event.

22. Consolidation Coal Co., Blacksville No. 1 Mine, WEST VIRGINIA (ID No. 46-01867) March 19, 1992; Explosion (4 Fatalities)

Note that although this disaster is in large part a surface accident, there were several people underground directly below the shaft that were affected. The fatalities at the surface were not counted in the event tree analysis, however, disposition of those underground was incorporated.

First indication of fire, explosion or inundation	10:20 am, March 19th.
Death of Miner 1, Miner 2, …., etc.	Victims 1, 2, 3, and 4 died instantly in the explosion; all were above ground at the cap works for the production shaft, where the methane build-up under the cap exploded from welding sparks. Three other miners on the surface were injured, two seriously. No miner underground was injured.
First knowledge of accident outside mine	Immediate; the explosion was heard and seen above ground, and initiated above ground at the top of the production shaft being capped.
First knowledge of accident elsewhere inside mine	All underground miners were immediately aware of the explosion, either by visible dust or noticing changing air currents
Actions and movements of the miners inby (downstream) of fire or explosion.	One miner was located alone approximately 650 ft from the bottom of the production shaft (top of which was ignition source). He experienced dust clouds impairing his vision and he had an SCSR but didn't use it. He felt his way to an exit portal, by which time the dust had cleared, and escaped with the hoist without problem. All other persons located underground (12 more) were together in the "2 west haulage" area. They noticed a mild rush of air. They were notified by phone to travel away from the explosion area to an emergency hoist facility. All were safely removed in three groups with the hoist, unimpaired.
Actions and movements of miners (outby) upstream of fire or explosion	Same as above (inby movements)
Miners barricade	No barricade – N/A
Rescue team enters mine	No rescue teams were required. Inspectors went in later, after miners were brought to surface.
Rescue team reaches miners	N/A
All miners and rescue team are out of mine	All miners out by 11:20 am
Distance of working section from surface of mine	No working section; mine was inactive. Miners were gathering equipment to remove from mine, in 2 areas. Closest miner was 650 ft from the bottom of the production shaft.
Extent of flame	The dewatering casing tube extended down the production shaft, and was filled with flame. Forces blew the cap off and flames shot out 30 ft into the air when released, with an orange hue signifying coal dust. Propagation inside the mine not clear; full investigation not pursued due to safety and closure of the mine.
Extent of forces	Initial inspection after blast showed forces caused damage over at least a 300 ft radius in the mine, with most severe damage in a 100 ft radius.

Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO. Stations would likely not have helped here. Miners below ground were all able to escape the mine easily except one miner who had to feel his way to an exit hoist due to dust. This miner had an SCSR that could have helped him get out, but he didn't need to use it. He escaped without further hindrance.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	No mine maps provided with the FMI copy of report. Mine was not a working mine and was being prepared for closure. Methane explosion occurred in a production shaft, under a concrete cap being prepared for sealing off the mine. Welding operations caused an ignition of built up methane and coal dust. Detonation of the mixture resulted. From report: "Pressures at the top of the shaft were approximately 1000 psig. A detonation of coal dust/methane accumulations of such high proportions has never been previously recorded in the coal mining industry."
Total number miners underground at the time of the accident	Thirteen
Number of miners impacted by the accident versus not impacted	One impacted, 12 not impacted
Of those miners impacted, number immediately killed	None
Of those miners impacted, number that escaped and evacuated	One
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Thirteen miners could have been neutrally affected by refuge stations. All were able to get out of mine without assistance.
Miners that escaped, escaped within what timeframe?	All out within approximately 1 hr
Miners that died, died within what timeframe?	Immediately, due to explosion, located above ground
Miners that were rescued, were rescued within what timeframe?	No rescue necessary: exited themselves unassisted

23. Fire Creek Inc. No. 1 Mine, VA. (ID No. 46-07512) January 16, 1991; Explosion (2 Fatalities)

First indication of fire, explosion or inundation	6:20 am January 16th, 1991.
Death of Miner 1, Miner 2, …., etc.	Miner 1 and Miner 2 died in the explosion at approximately 6:20 am, January 16th. Report is not clear on the exact cause of death; *FMI assumption*: asphyxiation within minutes of the explosion
First knowledge of accident outside mine	Approximately 7:00 am, January 16th
First knowledge of accident elsewhere inside mine	Approximately 6:45 am, January 16th
Actions and movements of the miners inby (downstream) of fire or explosion.	None, only twoners (victims) in mine, locate at ignition site. Found by rescuers close to the equipment being serviced by them.
Actions and movements of miners (outby) upstream of fire or explosion	None, only two miners (victims) in mine
Miners barricade	No barricade
Rescue team enters mine	10:00 am, January 16th
Rescue team reaches miners	Approximately 3:30 am January 22nd (progress had been halted to drill a borehole and check gasses.)
All miners and rescue team are out of mine	5:45 am, January 22nd all out of mine
Distance of working section from surface of mine	Approximately 4800 ft
Extent of flame	As far as 420 ft outby
Extent of forces	Effects of forces seen as far as 740 ft outby. 11 stoppings destroyed, extensive damage seen, debris widely scattered, damage to power center.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	Stations would likely not have helped here. Miners would have asphyxiated within minutes. A station would have needed to be very close to them to possibly help.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	This was a methane blast ignited by a cigarette lighter or match. Miners were servicing equipment at the face. Report did not include autopsy with exact cause of death (assume a combination of injury and suffocation).

Total number miners underground at the time of the accident	Two
Number of miners impacted by the accident versus not impacted	Both miners.
Of those miners impacted, number immediately killed	Both miners suffocated within minutes
Of those miners impacted, number that escaped and evacuated	None
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Two miners would have been neutrally affected by stations
Miners that escaped, escaped within what timeframe?	N/A
Miners that died, died within what timeframe?	Within minutes of the explosion, suffocated.
Miners that were rescued, were rescued within what timeframe?	Rescue process took almost six complete days (drilled boreholes to remediate gas levels). Miners were found dead.

24. Granny Rose Coal Company, No. 3 Mine (ID No. 15-16719) July 31, 1990; Explosion (3 Fatalities)

In the following case and in a few others to follow, it was not possible based on the historical information gathered to provide specific responses to the items in the left column. Instead a short narrative is provided which captures the essential facts.

First indication of fire, explosion or inundation	Summary report only available; brief narrative follows:
Death of Miner 1, Miner 2, …., etc.	This accident occurred in a very low coal seam that averaged 21 to 24 in. It was a blow-through of a coal pillar that was much thinner than miners thought when a production blast was detonated.
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	Three miners in the crosscut when the blow through occurred were killed instantly. Three other miners on the Section escaped. One was uninjured, and two others were hospitalized for smoke inhalation.
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	

Rescue team reaches miners	There appears to be no methane or coal dust involved in the explosion. It appears that the smoke was from the detonation of the explosives. No information on whether miners had or donned self rescuers. In this seam height, travel is on hands and knees. It is not known whether miners crawled to transportation and then escaped or whether they crawled out of the section to clear air.
All miners and rescue team are out of mine	
Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	No. Miners died instantly.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Not known
Number of miners impacted by the accident versus not impacted	Not known; six miners in the immediate area of the explosion were impacted.
Of those miners impacted, number immediately killed	Three were killed instantly.
Of those miners impacted, number that escaped and evacuated	Three miners survived, two suffered smoke inhalation and one was not injured. Summary report does not discuss how/when or whether the three survivors evacuated or were rescued, etc.
Of those miners impacted, number that barricaded	None barricaded
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All miners were neutrally affected, the three killed and the three who survived.
Miners that escaped, escaped within what timeframe?	Not known.
Miners that died, died within what timeframe?	The three victims were killed instantly.
Miners that were rescued, were rescued within what timeframe?	Not known.

25. Double R Coal Co., No. 1 Mine, VA (ID No. 44-05186) December 26, 1987; Explosion (1 Fatality)

First indication of fire, explosion or inundation	5:00 pm explosion.
Death of Miner 1, Miner 2, …., etc.	One miner died at approximately 5:00 pm, December 26, 1987.
First knowledge of accident outside mine	5:00 pm explosion dust plume was seen at surface.
First knowledge of accident elsewhere inside mine	No one else in mine; only one miner involved.
Actions and movements of the miners inby (downstream) of fire or explosion.	No one else in mine. Victim was located at the ignition source, near the working faces.
Actions and movements of miners (outby) upstream of fire or explosion	None, only one miner in mine (victim).
Miners barricade	No barricade.
Rescue team enters mine	9:40 pm December 26, 1987.
Rescue team reaches miners	Approximately 10:30 pm, January 3 1988 (numerous attempts were made before and after a borehole was dug, before the victim was reached.)
All miners and rescue team are out of mine	11:45 pm January 3, 1988.
Distance of working section from surface of mine	Approximately 5000 ft.
Extent of flame	May have been several thousand feet outby from the working face according to the coke deposits found.
Extent of forces	May have been as high as 15 psig static and 30 psig dynamic, not uncommon for a methane/coal dust explosion. 136 stoppings were destroyed out of 151 total. Forces caused extensive damage throughout the mine, even to the vehicles near the portal on the surface.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Stations would likely not have helped here. The victim was at the source of ignition and died instantly or was asphyxiated within minutes.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A

Miscellaneous Comments	Inadequate ventilation caused methane build up. Explosion was most likely ignited by an arcing battery charger. Victim was killed by asphyxiation. He had not left his vehicle.
Total number miners underground at the time of the accident	One
Number of miners impacted by the accident versus not impacted	One
Of those miners impacted, number immediately killed	One would have suffocated within minutes
Of those miners impacted, number that escaped and evacuated	None
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	One miner would have been neutrally affected by stations because he likely would not have survived long enough to find or use one. Blast forces may have destroyed stations.
Miners that escaped, escaped within what timeframe?	N/A
Miners that died, died within what timeframe?	Within a few minutes of explosion, by asphyxiation.
Miners that were rescued, were rescued within what timeframe?	N/A

26. Mid Continent Resources Inc., Dutch Creek No. 2 Mine, CO (ID No. 05-00469) January 8, 1987; Explosion (1 Fatality) (Partial report received)

First indication of fire, explosion or inundation	5:10 pm, January 8th, 1987.
Death of Miner 1, Miner 2, …., etc.	The one victim died of cardiac arrhythmia following a hospital stay for treatment of Ansul inhalation from a fire extinguisher. Death was 20 days after the mine fire, on January 28, 1987.
First knowledge of accident outside mine	Within a few minutes of the fire, a call was placed to the surface.
First knowledge of accident elsewhere inside mine	Not reported – report provided was not complete.
Actions and movements of the miners inby (downstream) of fire or explosion.	Miners at the face where the ignition happened were able to fight the gas fire successfully with fire extinguishers and water spray. Some miners used SCSRs but the miners actively fighting the fire wore them only part of the time. The victim was not wearing an SCSR when activating a fire extinguisher, and inhaled Ansul, becoming ill. He was given oxygen and removed from the mine with assistance. All other miners were not impeded from escaping if they wished to.
Actions and movements of miners (outby) upstream of fire or explosion	Not reported – report as provided to Foster-Miller was not complete.
Miners barricade	No barricade
Rescue team enters mine	No rescue team was needed, miners on scene dealt with fire and removed injured victim without impediment.
Rescue team reaches miners	See above.
All miners and rescue team are out of mine	Fire was extinguished at approximately 6:20 pm, January 8th. No information included on when all miners left mine.
Distance of working section from surface of mine	Not reported – report as provided to Foster-Miller was not complete.
Extent of flame	Fire was reported in the face area and along both ribs up to the cab of the continuous miner. An initial yellow ball of fire traveled outby towards the tail of the continuous miner, and a bluish flame crossed the mine roof.
Extent of forces	No information provided on strength of forces. It appears to have been a minor methane ignition, which caused a fire at the face only.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Refuge stations would likely have not helped here. Miners were able to fight the fire, and provide oxygen to one miner who was ill from inhalation of fire extinguisher chemical inhalation. The miners were able to evacuate at any time if they desired. SCSRs were available, and used at least part of the time by some of the miners.

If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	The report discussed only the area of the accident so the total number of miners in the mine is not known. There were at least four miners in the area of the fire.
Number of miners impacted by the accident versus not impacted	Information not provided for the whole mine (in our copy of the report). There were at least four miners in the area of the fire -all impacted
Of those miners impacted, number immediately killed	None
Of those miners impacted, number that escaped and evacuated	All (number not clear from report)
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All miners in the fire area would have been neutrally affected by rescue stations. The victim and the rest of the miners were able to escape without hindrance (victim needed assistance to evacuate by stretcher).
Miners that escaped, escaped within what timeframe?	Fire was out by approximately 6:20, (an hour or so after start) Miners could have left at any time.
Miners that died, died within what timeframe?	One miner died 20 days after the event.
Miners that were rescued, were rescued within what timeframe?	One miner was removed from mine on a stretcher after the fire was extinguished (approximately 1 to 2 hr after fire began).

27. Pyro Mining Co., Pyro No. 9 Slope, William Station Mine (ID No. 15-13881) August 9, 1986; Explosion (1 Fatality) (Summary report only)

First indication of fire, explosion or inundation	Approximately 6:30 pm, August 9, 1986.
Death of Miner 1, Miner 2, …., etc.	One miner died of injuries received one week after the explosion.
First knowledge of accident outside mine	Within a few minutes.

First knowledge of accident elsewhere inside mine	No information provided.
Actions and movements of the miners inby (downstream) of fire or explosion.	None inby.
Actions and movements of miners (outby) upstream of fire or explosion	One miner was immobilized, seriously injured from blast and burns, and was located in the main entryway in the blast line of the explosion. A second miner was located approximately 25 ft down a crosscut, approximately 100 ft outby the entryway from the blast site, out of the blast line, and was uninjured. A third miner was approximately 100 ft outby the entryway, and a few feet down a crosscut out of blast line and he was injured (burned). After the explosion, injured miners were immediately taken out of mine. No escape was impeded. The explosion ignited some loose coal dust, but methane levels were not explosive. Atmosphere seems to have been breathable after event.
Miners barricade	No barricade.
Rescue team enters mine	No rescue team was needed; miners present transported injured out of mine immediately after explosion.
Rescue team reaches miners	See above.
All miners and rescue team are out of mine	Approximately within 1 hr after event (immediate evacuation, no delays).
Distance of working section from surface of mine	No information provided.
Extent of flame	From diagram provided, flame extended approximately 140 ft inby the main entryway from the crosscut blast site, and approximately 6 ft inby in the parallel entryway.
Extent of forces	Information not provided. Injuries suggest it was a minor coal dust explosion.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	No, stations would not have helped here. The explosion caused injuries and burns, and some rock falls that later caught fire; however, nothing impeded escape of the miners, and air was still breathable after event.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	Minor coal dust explosion due to inadequate clean-up and misuse of explosives. Methane levels were not an issue.

Total number miners underground at the time of the accident	Information not provided. (Mine employs 428 underground in total.)
Number of miners impacted by the accident versus not impacted	No information provided on miners in other sections of mine
Of those miners impacted, number immediately killed	None immediately killed.
Of those miners impacted, number that escaped and evacuated	Three of three miners eventually got out, but one died a week later of injuries.
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Three of three miners would have been affected neutrally. There was a minor explosion causing injuries (but not noxious air); all were able to evacuate without impediment.
Miners that escaped, escaped within what timeframe?	Within approximately 1 hr of event (evacuated immediately).
Miners that died, died within what timeframe?	One miner died, one week after evacuation from mine, in hospital.
Miners that were rescued, were rescued within what timeframe?	Miners were immediately evacuated, including injured

28. M.S.W. Coal Company, No. 2 Slope Mine (ID No. 36-06279) December 11, 1985; Explosion (3 Fatalities)

First indication of fire, explosion or inundation	2.00 pm December 11th explosion occurred, methane ignited by shot charges deliberately detonated.
Death of Miner 1, Miner 2, …., etc.	The report is not clear as to exactly when each of the three miners died, but it is assumed that the two miners closest to the explosion point were either killed instantly by the blast, or were asphyxiated very soon after. The third miner who died was further outby the explosion point than the others, at the coal loading area. He proceeded inby shortly after the explosion to attempt to help, but was asphyxiated quickly.
First knowledge of accident outside mine	Within a few minutes of the explosion.
First knowledge of accident elsewhere inside mine	There were only five miners underground, all were together near the explosion point
Actions and movements of the miners inby (downstream) of fire or explosion.	None – No miners were located inby the explosion point.

Actions and movements of miners (outby) upstream of fire or explosion	Two miners closest to the explosion point were either killed instantly by the blast, or were asphyxiated very soon after. The third miner who died was further outby the explosion point than the others, at the coal loading area. He proceeded inby shortly after the explosion to attempt to help, but was asphyxiated quickly. A fourth miner injured in the blast, survived since he was further outby and in a breast way out of the direct blast line. The fifth miner was an uninjured survivor who had remained outby and notified the surface.
Miners barricade	No barricade was constructed or attempted.
Rescue team enters mine	MSHA personnel first entered mine at 3:45 pm, December 11th to attempt rescue.
Rescue team reaches miners	First miner reached approximately between 4 pm and 5 pm, December 11th; body couldn't be recovered until 5:40 pm.
All miners and rescue team are out of mine	All rescue teams and miners were out of the mine at approximately 9:30 to 10 pm, December 11th.
Distance of working section from surface of mine	Approximately 1750 to 2000 ft.
Extent of flame	Sections of the mine were damaged and inaccessible for inspection. Opinions were compiled from autopsies and survivor testimony. Flame traveled from explosion point at least 115 ft to where miners were located.
Extent of forces	As above, limited information provided. Force traveled outby at least 115 ft to the miners.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	Stations probably would not have helped here. Three miners were killed, two instantly from explosion force, and a third from asphyxiation during a rescue attempt without an SCSR. One miner injured had managed to leave the area after the explosion and was found alive. One miner was uninjured and able to escape without a station.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	Methane explosions can either kill instantly or asphyxiate miners within minutes afterwards. There would be no time to reach and enter a refuge station unless SCSRs were used immediately. If the third miner had decided not to attempt rescue (without an SCSR), a station may have been positively or neutrally effective for that one miner.
Total number miners underground at the time of the accident	Five

Number of miners impacted by the accident versus not impacted	Five
Of those miners impacted, number immediately killed	Two
Of those miners impacted, number that escaped and evacuated	One
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Difficult to be conclusive due to limited information provided. Overall, all were neutrally affected. Two were killed instantly. One died trying to save others but could have moved outby to safety. The injured miner was breathing but not mobile. One miner was free to escape the mine unhindered.
Miners that escaped, escaped within what timeframe?	One miner could have escaped immediately, but stayed to help others.
Miners that died, died within what timeframe?	Two instantly from explosion, one miner approximately 1 to 30 min later, asphyxiated while moving inby to help others
Miners that were rescued, were rescued within what timeframe?	3 to 4 hr

29. R and R Coal Company, No. 3 Mine (ID No. 44-06023) August 19, 1985; Post Explosion Toxic Gas (3 Fatalities)

First indication of fire, explosion or inundation	Summary report only available; brief narrative follows: During the afternoon of August 15, 1985, a production blast was detonated in the face of the No. 3 Mine. Miners were outside the mine having lunch during the blast. Coal was being hauled directly from the face outside using scoops. It is apparent that the face was not very far inby from the mine surface. At approximately 4:00 pm one scoop became stuck in the face area and the operator became overcome by CO. Three other miners attempted rescue and also were overcome by CO. The first miner regained consciousness and dragged one of the other miners to fresh air. While attempting a second rescue he was again overcome and died. Other miners rescued the one survivor and recovered the three victims. None of the miners were equipped with SCSRs . The presumed shallow depth of these workings may not have required refuge stations.
Death of Miner 1, Miner 2, …., etc.	
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	
Rescue team reaches miners	
All miners and rescue team are out of mine	

Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO; not likely. Three died immediately, one was too injured to escape or enter a station (and was later rescued).
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Four – Summary report is not specific but this can be inferred from narrative.
Number of miners impacted by the accident versus not impacted	All four.
Of those miners impacted, number immediately killed	One miner overcome by CO; two others died attempting to rescue him.
Of those miners impacted, number that escaped and evacuated	None escaped (the fourth miner also attempted to help rescue the others but was overcome; he survived).
Of those miners impacted, number that barricaded	None – N/A in this case.
Number of barricaded miners rescued alive	N/A –- None barricaded, though one miner was rescued.
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All four miners were neutrally affected.
Miners that escaped, escaped within what timeframe?	N/A –- None successfully escaped.
Miners that died, died within what timeframe?	Summary report is not specific - first miner died quickly; others died some time later while trying to rescue him.
Miners that were rescued, were rescued within what timeframe?	Summary report does not say.

30. Pennsylvania Mines Corp., Greenwich Collieries No. 1 Mine (ID No. 36-02405) February 16, 1984; Explosion (3 Fatalities)

First indication of fire, explosion or inundation	Summary report only available; brief narrative follows: At approximately 4:30 am on February 16, 1984, a methane gas explosion occurred on the D-3 Longwall Section. Three miners working on a pump in the D-3 area were killed instantly by the explosion. Four miners in the adjacent D-5 Longwall section were knocked down and severely burned but were able to escape. There was also evidence of flame in the D-1 section. There is no data on the use of self rescuers or how the four survivors escaped. It is evident that significant forces and flame spread to the adjacent D-5 Longwall.
Death of Miner 1, Miner 2, …., etc.	
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	
Rescue team reaches miners	
All miners and rescue team are out of mine	
Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Three miners killed instantly.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Fourteen – Summary report is not specific but this can be inferred from narrative.
Number of miners impacted by the accident versus not impacted	All 14 were neutrally affected
Of those miners impacted, number immediately killed	Three were killed instantly by the explosion
Of those miners impacted, number that escaped and evacuated	The remaining 11 escaped and evacuated

Of those miners impacted, number that barricaded	None – All survivors escaped.
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	None – All survivors escaped and all victims died instantly.
Miners that escaped, escaped within what timeframe?	Not known but presumably in a timely fashion.
Miners that died, died within what timeframe?	All three victims died instantly.
Miners that were rescued, were rescued within what timeframe?	N/A – No miners were rescued.

31. Helen Mining Co., Homer City Mine, PA (ID No. 36-00926) July 3, 1983; Explosion (1 Fatality)

First indication of fire, explosion or inundation	Approximately 5:40 pm, July 3 explosion occurred.
Death of Miner 1, Miner 2, …., etc.	One miner died within minutes of the explosion by asphyxiation. He was at the ignition site.
First knowledge of accident outside mine	Approximately 6:00 to 6:15 pm July 3rd.
First knowledge of accident elsewhere inside mine	Approximately 6:00 to 6:15 pm.
Actions and movements of the miners inby (downstream) of fire or explosion.	No activity inby the explosion.
Actions and movements of miners (outby) upstream of fire or explosion	One miner (the victim) was driving a personnel carrier which arced and caused a methane/coal dust explosion. He was asphyxiated within minutes. No attempt to use an SCSR was noted.
Miners barricade	No barricade.
Rescue team enters mine	Approximately 1:15 am, July 4th.
Rescue team reaches miners	10:45 am, July 5th.
All miners and rescue team are out of mine	12:50 am, July 6th.
Distance of working section from surface of mine	Approximately 2- 3000 ft.
Extent of flame	Explosion was methane and coal dust. Flame extended approximately 1300 ft

Extent of forces	Block stoppings were blown out. Damage was extensive. Pressures may have been as high as static: 15 psig, and dynamic pressure: 30 psig. The victims body was not badly damaged physically (but was burned). He died of CO poisoning and smoke inhalation.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Stations would not have helped here. The one victim was at the ignition point of a violent methane/coal dust blast and was asphyxiated within minutes. No attempt appears to have been made to use an SCSR. He wouldn't have had time to travel to a station. A second miner was in a different section of the mine, and was able to escape without any problem.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Two
Number of miners impacted by the accident versus not impacted	One impacted, one not impacted
Of those miners impacted, number immediately killed	One would have asphyxiated within minutes
Of those miners impacted, number that escaped and evacuated	None
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Two miners would have been neutrally affected by stations. One died immediately; one escaped without injury.
Miners that escaped, escaped within what timeframe?	One miner unaffected by blast could have evacuated immediately, but initially decided to search for the second miner.
Miners that died, died within what timeframe?	Within a few minutes, by asphyxiation.
Miners that were rescued, were rescued within what timeframe?	None rescued; one of two miners underground was unaffected and could have evacuated immediately.

32. P and P Coal Company, Inc., No. 2 Mine (ID No. 44-02274) July 7, 1977; Explosion (4 Fatalities)

First indication of fire, explosion or inundation	Summary report only available; brief narrative follows: At approximately 10:00 am on July 7, 1977, a methane gas explosion occurred in the 1 Left Section off "C" Mains. The ignition was triggered by a cigarette lighter found at the accident scene. Four miners at the site of the explosion were killed instantly. Forces dislodged posts and destroyed stoppings 900 ft outby the faces of 1 Left. Forces extended into the 2 Left and 3 Left Sections where miners felt the concussion and dissipated near the No. 3 belt drive 3500 ft from the explosion. Flame burned all four victims and burned clothing off their bodies. There was little to no coal dust involved in the explosion and flame did not extend very far from its source. The 1 Left crew notified the surface by phone immediately after the explosion. Outby miners were in heavy dust immediately after the explosion but proceeded to 1 Left in a rescue attempt. Initially they acted on their own but were later directed to by mine management on the surface. They encountered heavy smoke and difficulty in breathing and attempted to reestablish ventilation into the section until ordered to withdraw by MSHA. Rescue teams entered the mine at approximately 2:30 pm on 7/07/1977.
Death of Miner 1, Miner 2, …., etc.	
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	
Rescue team reaches miners	
All miners and rescue team are out of mine	
Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	No. Four miners were killed instantly. Sixteen successfully escaped.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	Victims were found by the rescue teams and removed to the surface by 2:04 am on 7/08/1977. Victims were severely burned and there were no attempts to don self rescuers or escape.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None

Total number miners underground at the time of the accident	Twenty – Summary report is not specific but this can be inferred from narrative.
Number of miners impacted by the accident versus not impacted	Four were directly impacted and the other 16 were indirectly impacted in that they felt the effects of the explosion (air blast, dust, etc.).
Of those miners impacted, number immediately killed	All four miners directly impacted were killed instantly.
Of those miners impacted, number that escaped and evacuated	None of the four directly impacted escaped (killed instantly); all 16 other miners escaped and evacuated.
Of those miners impacted, number that barricaded	N/A – All directly impacted were killed instantly.
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	All 20 miners would have been neutrally affected: four were killed instantly and could not have used a station; the other 16 were able to readily escape and would not have needed to use stations.
Miners that escaped, escaped within what timeframe?	Summary report does not say: some of the 16 who escaped the effects helped in trying to reach the 4 missing miners.
Miners that died, died within what timeframe?	All 4 were killed instantly.
Miners that were rescued, were rescued within what timeframe?	N/A – No miners were rescued.

33. Oakwood Red Ash Coal Corp., No. 4 Mine, VA (ID No. 44-01740) September 25, 1973; Explosion (2 Fatalities)

First indication of fire, explosion or inundation	Approximately 11:45 am, September 25th.
Death of Miner 1, Miner 2, …., etc.	Death of two miners occurred within minutes of explosion, by asphyxiation. They had attempted to use SCSRs but failed. Proximity to the cart (ignition source) showed they didn't move far after the explosion.
First knowledge of accident outside mine	A few minutes after explosion a call was made to surface mechanic.
First knowledge of accident elsewhere inside mine	Immediate knowledge, since they felt blast force and winds.
Actions and movements of the miners inby (downstream) of fire or explosion.	No activity inby the explosion.

Actions and movements of miners (outby) upstream of fire or explosion	No mine maps were provided with the report, but from descriptions it seems the explosion was outby the main working areas where 30 miners were located. They were not trapped or injured by blast, and easily evacuated. Two miners that had taken a personnel carrier to check on earlier workings were asphyxiated when an arc from the carrier ignited methane.
Miners barricade	No barricade.
Rescue team enters mine	Approximately 1 to 1:45 pm.
Rescue team reaches miners	5:45 am, September 26th.
All miners and rescue team are out of mine	8:30 am, September 26th.
Distance of working section from surface of mine	Not reported, but ignition point was 1350 ft from active faces.
Extent of flame	Flame extended about 180 ft outby the personnel carrier in the intake entries, and 570 ft outby the personnel carrier.
Extent of forces	No figure estimate provided. Forces radiated out from the personnel carrier. Several stoppings were blown out. Employees 2300 ft away outby felt a strong concussion. Employees 6000 ft away outby felt a slight reversal of the air current. One explosion door was forced open on one of the surface fans.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	YES – A refuge station might have helped here, depending on location relative to the two suffocated miners.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	YES – If a refuge station was in place it would have needed to withstand the methane/coal dust explosion.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	YES – Placement per guidelines would have been acceptable.
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Thirty-two
Number of miners impacted by the accident versus not impacted	Thirty-two
Of those miners impacted, number immediately killed	Two asphyxiated within minutes of the explosion
Of those miners impacted, number that escaped and evacuated	Thirty

Of those miners impacted, number that barricaded	No barricade
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Two miners could have been positively affected by stations, had a station been very close to the ignition point. Thirty miners would have been neutrally affected by stations because they were not trapped or exposed to noxious air.
Miners that escaped, escaped within what timeframe?	All miners except the two killed could have left immediately, but some chose to stay for rescue attempt.
Miners that died, died within what timeframe?	A few minutes, from asphyxiation.
Miners that were rescued, were rescued within what timeframe?	No successful rescue. Two dead miners were found after approximately 18 hr.

34. The Buckeye Coal Company, Nemacolin Mine (ID No. 36-00904) March 26, 1971; Fire (2 Fatalities)

First indication of fire, explosion or inundation	Summary report only available; brief narrative follows: At approximately 10:20 am on 3/26/71, a fire occurred in the 118 Straight Mains Section caused by an electrical short in the trolley system. Smoke on the section alerted miners on the section of a fire outby the section. The crew assembled to escape through the left return entries and assembled outby the check curtain to start their escape. Two miners decided to return to their machines for their flame safety lamps. There was dense smoke in the last open crosscut. One miner returned to the group. The second never returned. The crew continued their escape to the mouth of the section. At that point, it was discovered that a second miner was also missing. Miners outby the source of the fire escaped successfully. At approximately 12:45 pm on 3/26/1971, it was decided to drill holes from the surface into the section in an attempt to contact and rescue the trapped miners. Between 3/26 and 3/31/1971, 90 boreholes were drilled into the mine workings in and around the fire area. Geo-phones were used to try to detect the miners and various materials were introduced to try to control the fire. All were unsuccessful. On 3/31/1971, it was concluded that the missing miners could not have survived and the decision was made to flood the mine. On 4/15 mine rescue teams reentered to directly fight the fire. On 4/16 an inspector from the
Death of Miner 1, Miner 2, …., etc.	
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	
Rescue team reaches miners	
All miners and rescue team are out of mine	
Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	

If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	state of PA accidentally drowned during firefighting operations. On 5/15, it was decided to inject nitrogen into the fire area. On 5/29, rescue teams returned underground to build seals around the fire area. Twenty-five bulkheads were completed by 8/10/1971. The bulkheaded area was then flooded for 17 months. Mine rescue teams reentered the mine and the 118 Straight Mains Section at 5:15 am on 9/15/1972. One victim was located at 3:10 am on 9/16 and the second on 9/21/1972.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	
Miscellaneous Comments	It is not known if miners donned filter-type self rescuers during escape. It is also not known why the one victim decided to return to his machine in a smoky environment to retrieve his flame safety lamp. He either became disoriented due to poor visibility or was overcome by CO. There is no way to know what happened to the second victim or whether he attempted to don a self rescuer. All the other miners escaped successfully. In this incident the availability of a refuge station may have had a negative neutral or positive impact. Because of the magnitude and spread of the fire, the miners could have entered a station instead of escaping. Rescue teams may or may not have been able to reach them because of the rapid spread of the fire. Assuming the station was pre-surveyed and a drill site located and prepared on the surface, holes could have been drilled to supply air and an escape borehole could have been drilled to the station.
Total number miners underground at the time of the accident	One hundred twenty-five.
Number of miners impacted by the accident versus not impacted	Summary report is not specific (presume only 11 impacted versus 114 not impacted).
Of those miners impacted, number immediately killed	None immediately killed.
Of those miners impacted, number that escaped and evacuated	Nine of the 11 impacted escaped and evacuated.
Of those miners impacted, number that barricaded	No attempts to barricade; miners were able to escape except for two who also did not appear to have attempted to barricade.
Number of barricaded miners rescued alive	N/A – No barricaded miners and neither of the two missing miners were rescued.
Number of barricaded miners that died	N/A – No barricaded miners, though two miners went missing during the escape and died.

No. miners that could have been positively, negatively, neutrally affected by stations	Speculation allows for numerous possible scenarios here: *Scenario 1*: Nine miners *could* have been negatively affected if they'd elected to huddle in a station rather than continue their escape attempt. They might have perished since it is possible that rescuers would not have been able to reach them due to the rapid spread of the fire. In this case, the two miners who perished would have been neutrally impacted. *Scenario 2*: all 11 miners could have survived in the station resulting in nine neutrally affected and two positively affected. *Scenario 3:* the two miners who perished *could* have been positively affected if they retreated to a station after they became disoriented and realized they could not rejoin their fellow miners, assuming rescuers reached them in time. (We considered only Scenario 2 in our event tree analysis).
Miners that escaped, escaped within what timeframe?	Report does not say – presumably the nine impacted miners and the other 114 not impacted escaped in a timely fashion.
Miners that died, died within what timeframe?	Report does not say – presumably the two miners who separated and were lost died in a relatively short time due to smoke and CO inhalation. It is not known if they donned and used self-rescuers.
Miners that were rescued, were rescued within what timeframe?	No miners were rescued.

35. Pyro Mining Co., Pyro Mine No. 2, KY (ID No. 15-02131) November 30, 1970; Gas Ignition (1 Fatality)

First indication of fire, explosion or inundation	11:30 am, November 30th, 1970.
Death of Miner 1, Miner 2, …., etc.	One miner died between approximately 11:35 and 12:00 pm, Novembr 30 of asphyxiation.
First knowledge of accident outside mine	A few minutes after initial event a miner contacted surface staff by telephone.
First knowledge of accident elsewhere inside mine	A few minutes after initial event a miner contacted other section by telephone.
Actions and movements of the miners inby (downstream) of fire or explosion.	Fifty-eight unaffected miners in other working sections escaped unassisted.
Actions and movements of miners (outby) upstream of fire or explosion	Two affected miners were at the ignition site, and ran to escape. One found an escape route; the other didn't, and was asphyxiated.

Miners barricade	No barricade.
Rescue team enters mine	Miners returned to area with SCSRs between approximately 12:00 -12:30 pm Novembr 30.
Rescue team reaches miners	Victim found at approximately 12:30 pm, November 30.
All miners and rescue team are out of mine	Info. not provided in the summary report received by FMI.
Distance of working section from surface of mine	Info. not provided in the summary report received by FMI.
Extent of flame	Info. not provided in the summary report received by FMI.
Extent of forces	Info. not provided in the summary report received by FMI
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	YES – Refuge stations would have helped in this situation. One miner was mobile, in need of air, and trying to find a way out. He survived for a time before being suffocated. A station would have positively affected this situation.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	Not in this case; it was a gas ignition without explosion. There was, however, a fire spreading.
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	There is reason to believe that placement guidelines would not have worked here, since the miners were inspecting/ surveying previously worked out areas. Since this wasn't a working section, it is not clear what guidelines would be applicable. Stations may have been dismantled and/or moved away to other active sections.
Miscellaneous Comments	Gas ignition was in a previously mined area, where work had stopped approximately 5 days before. Cigarette lighter ignited gas. Two affected miners were not wearing SCSRs.
Total number miners underground at the time of the accident	Sixty
Number of miners impacted by the accident versus not impacted	Two impacted, 58 not impacted
Of those miners impacted, number immediately killed	None immediately and one was killed while attempting to escape.
Of those miners impacted, number that escaped and evacuated	One
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A

No. miners that could have been positively, negatively, neutrally affected by stations	One miner could have been positively affected by refuge stations: the victim could not make his way out of the affected area before asphyxiation; however, he did travel some distance and responded to shouts some minutes later indicating he might have reached a station or used fresh air. One miner affected was able to escape and so was neutrally affected. Fifty eight miners in other sections would have been neutrally affected.
Miners that escaped, escaped within what timeframe?	Report not clear on time miners left mine, but all were able to leave unimpeded at any time. Miners were instructed to evacuate at approximately 12:30 to 1 pm November 30 and a fire fighting team entered mine. Not clear from report when fire was extinguished.
Miners that died, died within what timeframe?	Within approximately 30 min, asphyxiation. One miner searching for the victim some minutes after the event heard a low moaning in response to calls that he attributed to the victim, indicating he was still alive. However when rescuers returned with SCSRs, victim had asphyxiated.
Miners that were rescued, were rescued within what timeframe?	Victim was found dead approximately 30-45 min after event.

36. The Helen Mining Co., Homer City Mine, PA (ID No. 36-00926) April 10, 1970; Explosion (1 Fatality)

First indication of fire, explosion or inundation	3:40 am, April 10, 1970 explosion occurred and a fire resulted.
Death of Miner 1, Miner 2, …., etc.	The victim died between 3:40 and 5:00 am April 10, when he was found (died by asphyxiation).
First knowledge of accident outside mine	Not clear exactly from report (likely within 1 hr after event).
First knowledge of accident elsewhere inside mine	The 15 affected miners close to the event all knew immediately (felt blast etc.). Report does not state when the other 19 miners in other areas found out.
Actions and movements of the miners inby (downstream) of fire or explosion.	Of the 5 men near the ignition source (continuous miner sparks), three were injured and one of those was unconscious. The unconscious miner was found and moved by stretcher to surface approximately 4:10 am. The victim who died was found at 5:00 pm near the nearest crosscut to the continuous miner. By 5:30 am, all affected miners were out of mine. The 10 men in the adjacent section, who felt the blast, were all evacuated without a problem.
Actions and movements of miners (outby) upstream of fire or explosion	The 19 miners in other areas of the mine all evacuated without trouble when they found out.
Miners barricade	No barricade.

Rescue team enters mine	No rescue team was required to remove miners. The miners in the area donned SCSRs as necessary and removed the injured/ dead men. This activity began immediately after the event.
Rescue team reaches miners	Injured miners found between 3:40 and 4:00 am; victim found at 5:00 am. Note: injured were aided by other miners.
All miners and rescue team are out of mine	All affected miners were removed by 5:30 am; other miners stayed below ground to fix ventilation and fight fires.
Distance of working section from surface of mine	No map was provided with the report as received by FMI. Information not clear as to distance.
Extent of flame	Flame spread approximately 152 ft outby explosion point, and 170 ft in other directions.
Extent of forces	Forces damaged three overcasts, numerous curtains and brattice cloth checks up to 450 ft outby the face.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO. Refuge stations would not have helped in this disaster. One miner was found dead not far from his vehicle without sign of SCSR use. Others who were injured could not easily move or were not conscious.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	Coal dust was a factor in the explosion. Methane ignited via sparks from a continuous miner cutting into sandstone.
Total number miners underground at the time of the accident	Thirty-four
Number of miners impacted by the accident versus not impacted	Fifteen
Of those miners impacted, number immediately killed	None immediately killed. One died before he could be rescued.
Of those miners impacted, number that escaped and evacuated	Fourteen
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A

No. miners that could have been positively, negatively, neutrally affected by stations	All 15 impacted were neutrally affected since the presence of a station would not have changed the outcome.
Miners that escaped, escaped within what timeframe?	All affected miners were removed by 5:30 am; other miners stayed below ground to fix ventilation and fight fires.
Miners that died, died within what timeframe?	The victim died between 3:40 and 5:00 am April 10, when he was found (died by asphyxiation).
Miners that were rescued, were rescued within what timeframe?	All affected miners were removed by 5:30 am; other miners stayed below ground to fix ventilation and fight fires.

37. Clinchfield Coal Co., Compass No. 2 Mine, WEST VIRGINIA (ID No. 46-01312) April 2, 1970; Explosion (1 Fatality)

First indication of fire, explosion or inundation	3:40 pm, April 2nd, 1970.
Death of Miner 1, Miner 2, …., etc.	One miner died at approximately 3:40 pm in the explosion.
First knowledge of accident outside mine	5 to 10 min after explosion.
First knowledge of accident elsewhere inside mine	Immediately: other miners saw dust clouds, felt blast pressure.
Actions and movements of the miners inby (downstream) of fire or explosion.	Miners inby of the explosion were forced to evacuate by the dust and were able to do so unassisted.
Actions and movements of miners (outby) upstream of fire or explosion	None
Miners barricade	No barricade.
Rescue team enters mine	Between approximately 4 pm and 6 pm April 2.
Rescue team reaches miners	Victim found at approximately 6 to 7 pm April 2.
All miners and rescue team are out of mine	Victim removed from mine at approximately 6 to 7 pm April 2. Inspectors/rescuers team entered mine at 7:30 pm April 2, and left mine at 11:50 pm April 2.
Distance of working section from surface of mine	Information not provided.
Extent of flame	Approximately 2100 ft inby the ignition point and 600 ft outby.
Extent of forces	Forces extended approximately 2500 ft inby explosion point and approximately 900 ft outby. Considerable physical damage: 10 to 20 stoppings blown out, belt drive and conveyor damaged for approximately 400 ft inby. Ventilation facilities and electrical installations damaged.

Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Refuge stations would likely *not* have helped in this disaster, since the one miner killed was at or near the ignition point and likely instantly killed. No attempt was made to use an SCSR. The other miners were not prevented from escaping, and did not need SCSRs to make their way out.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	Methane build up due to fan outage, barometric pressure change, and arcing from electric motor caused explosion near a gob-sealed area.
Total number miners underground at the time of the accident	Eleven
Number of miners impacted by the accident versus not impacted	Eleven of 11 impacted
Of those miners impacted, number immediately killed	One
Of those miners impacted, number that escaped and evacuated	Ten
Of those miners impacted, number that barricaded	None
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Eleven miners would have been neutrally affected by refuge stations: one was killed by the explosion and the others escaped unassisted.
Miners that escaped, escaped within what timeframe?	Immediately able to evacuate mine unassisted.
Miners that died, died within what timeframe?	Immediately, or within minutes if suffocation occurred (report does not conclude exact cause of death, although severe burns were noted on the victim and he was blown 6 ft from his vehicle.)
Miners that were rescued, were rescued within what timeframe?	The one victim was found and removed within 2 to 3 hr of the explosion. The mine employees retrieved the body themselves, without SCSRs needed.

38. Black Wolf Coal Company, Inc., Quecreek No. 1 Mine (ID No. 36-08746) July 24, 2002; Nonfatal Entrapment by Inundation (No Fatalities)

Although this is a nonfatal event it is significant for two reasons: it involves a large number of miners that were successfully rescued and it involves inundation that was not common in the disasters studied. The results were incorporated in the event tree although there were no fatalities.

First indication of fire, explosion or inundation	Continuous miner broke through into old flooded works at 8:45 pm July 24, 2002, so the inundation was known about immediately on 1-Left Section.
Death of Miner 1, Miner 2, …., etc.	No miners died; all were eventually rescued (detailed below).
First knowledge of accident outside mine	Personnel from 1-Left notified the outside and 2-Left soon after the inundation (the report does not specify an exact time).
First knowledge of accident elsewhere inside mine	See above (2-Left was notified concurrent with the outside).
Actions and movements of the miners inby (downstream) of fire or explosion.	No miners were downstream because the inundation occurred right at the working face on 1-Left. The actions of the 1-Left miners consisted of gathering together and making a variety of attempts to escape through each of the seven entries of 1-Left. The miners made it all the way to the mouth of the section (about 3,100 ft) ultimately determining that all entries were flooded to the roof with water and escape was impossible. Eventually they built block walls across various openings as water dams and barricaded themselves within the face area in the No. 1 entry, the furthest entry on the left side of the section and the high point in the section.
Actions and movements of miners (outby) upstream of fire or explosion	All other miners in the mine (2-Left section and a few outby workers) escaped to the surface. The last miners to leave the mine barely made it, having to pass through a low-headroom dip within the mains where the water had risen to the point where they needed to crouch and crawl with only their heads above the water.
Miners barricade	Miners were in the process of building the block walls when an emergency borehole being drilled penetrated the section in No. 4 entry - the time was noted as 5:06 am July 25, about 8 hr after the accident. By 11:40 am July 25 the water had risen to the point where they moved to the No. 1 entry.
Rescue team enters mine	N/A. Rescue teams did not enter the mine, but a rescue hole was drilled and entered the section some time before 12:55 am on July 28.
Rescue team reaches miners	N/A. See above.
All miners and rescue team are out of mine	All miners reached the surface through the rescue hole between 12:55 am and 2:45 am on July 28 after being trapped between 76 and 78 hr.

Distance of working section from surface of mine	4,500 ft from the portals to the turn into 1-Left + 3,100 to the 1-Left faces = about 7,600 ft.
Extent of flame	N/A (inundation).
Extent of forces	N/A (inundation).
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	NO – Ultimately the men had to locate in the face of No. 1 entry and a station definitely would NOT have been located there and any other locations within 1,000 to 2,000 ft from the faces would have been inundated with water. If a station was accessible, the men could have taken some of its supplies (food, water, medical supplies as needed, etc.) to their barricade area for use while there. The station would not likely have been designed to resist significant pressure head and would not have provided safe refuge once the water level became too high.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A (inundation).
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A (inundation) – Stations located per guidelines or any other logical rationale for positioning would not have helped in this case (see discussions above).
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Eighteen
Number of miners impacted by the accident versus not impacted	Nine were directly impacted and were trapped; nine others were impacted but were able to escape.
Of those miners impacted, number immediately killed	N/A – None killed.
Of those miners impacted, number that escaped and evacuated	Nine were able to escape.
Of those miners impacted, number that barricaded	The nine miners that were trapped.
Number of barricaded miners rescued alive	All nine were rescued.
Number of barricaded miners that died	N/A – None killed.
No. miners that could have been positively, negatively, neutrally affected by stations	All 18 miners in the mine would have been neutrally impacted because the nature of the inundation made it impossible for them to make proper use of stations. Had a station existed, however, the nine trapped miners could have taken some of its supplies (food, water, medical supplies as needed, etc.) to their barricade area for greater comfort while there.

Miners that escaped, escaped within what timeframe?	The nine miners that escaped were out by 9:10 pm, about 25 min after the 8:45 inundation.
Miners that died, died within what timeframe?	N/A – None killed.
Miners that were rescued, were rescued within what timeframe?	Rescued within 76 to 78 hr.

Disasters that are not directly applicable to current intended use of refuge stations

39. Consolidation Coal Co., Loveridge No. 22 mine (ID No. 46-01433) February 6, 1986; Multiple Suffocation Accident (5 Fatalities)

This event is not applicable to refuge stations and is provided for information. It involves a significant number of deaths by suffocation and thus was evaluated. The data was not included in the event tree analysis.

First indication of fire, explosion or inundation	11 am February 6, 5 of 7 men walking on a coal pile in a raw coal storage bin fell into a cavity in the pile and were suffocated.
Death of Miner 1, Miner 2, …., etc.	All the men fell in and were suffocated together, at approximately 11 am, February 6
First knowledge of accident outside mine	Approximately 11:05 am, February 6
First knowledge of accident elsewhere inside mine	N/A, accident occurred at the surface
Actions and movements of the miners inby (downstream) of fire or explosion.	N/A, accident occurred at the surface
Actions and movements of miners (outby) upstream of fire or explosion	N/A, accident occurred at the surface
Miners barricade	No barricade was built, men were suffocated within minutes of the event
Rescue team enters mine	Rescue began immediately; men on the scene were secured with ropes and began digging for victims. Conveyor belt haul-off feeders under the trapped men were turned on after a few minutes of fruitless digging.
Rescue team reaches miners	11:40 am, February 6: first body recovered from feeder chute under coal pile, others soon after.
All miners and rescue team are out of mine	All 5 bodies recovered by 12.07 pm, February 6. Coal feeders were left running until 3:30 pm, February 6 to be sure no other persons were also buried. Rescue operations were complete at 3:30 pm February 6.
Distance of working section from surface of mine	N/A
Extent of flame	N/A, no flame
Extent of forces	N/A, no explosion

Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	N/A – Stations would not be applicable in this disaster due to the accident occurring out of the mine on the surface. The 5 victims were buried and suffocated too rapidly for emergency air or refuge areas to have been plausible.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	No explosion occurred in this disaster, stations would not have needed to be explosion proof
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	Stations N/A in this situation.
Miscellaneous Comments	*FMI assumption*: this is a special case not applicable to refuge stations. The disaster took place on the surface, in the raw coal pile bin and it may be fair to say that more strict procedures for ensuring safety while walking on coal piles may avoid future disasters of this type.
Total number miners underground at the time of the accident	N/A – This was a surface accident and is not applicable to this study
Number of miners impacted by the accident versus not impacted	N/A
Of those miners impacted, number immediately killed	N/A
Of those miners impacted, number that escaped and evacuated	N/A
Of those miners impacted, number that barricaded	N/A
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	N/A
Miners that escaped, escaped within what timeframe?	N/A
Miners that died, died within what timeframe?	N/A
Miners that were rescued, were rescued within what timeframe?	N/A

40. Clinchfield Coal Company, Moss No. 3 Portal A Mine (ID No. 44-01642) April 4, 1978; Inundation of Carbon Dioxide (5 Fatalities)

This report is not directly applicable to refuge stations and is provided for information. It involved a significant number of deaths by suffocation and thus was evaluated. It may be of use in specifying refuge stations for use in noxious atmospheres. The data is not included in the event tree analysis.

First indication of fire, explosion or inundation	Not applicable to this analysis –summary only provided below: The mine was driving a single entry with a continuous miner 265 ft from the outside to connect to a sealed gob that was filling with water. The entry was to be a water drainage tunnel. The mine drilled test holes ahead of mining and intersected the sealed area. Their only concern was high methane gas concentrations and not CO_2 or oxygen deficiency. They tested with a methanometer but did not have oxygen or CO_2 instruments. The air in the gob was pressurized due to it filling with water and a falling barometer so air was coming through the borehole into the entry. The air showed low methane, so mining progressed. When the continuous miner cut into the sealed area CO_2 flooded the entry. At the time the miner cut into the sealed area there were four men at the face. Two men were overcome by lack of oxygen and high CO_2 and died. Two men survived. One dragged the second to safety. This was spring of 1978, so none of the four had SCSRs which might have helped. Three miners who were outside when the breakthrough occurred attempted rescue with no oxygen supplies. One died. Representatives from National Mine Service Company, who were on the surface doing repairs to a continuous miner, also attempted rescue without oxygen. One died. MSHA officials, including the District and Subdistrict Managers and a Supervisory Mining Engineer arrived on the property with a Clinchfield Manager of Safety. They stopped enroute to check the tunnel progress not knowing that an inundation had occurred. They joined the rescue attempts also without oxygen. The Subdistrict Manager died. Eventually, rescue teams arrived, entered under oxygen, and recovered the five
Death of Miner 1, Miner 2, …., etc.	
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	
Rescue team reaches miners	
All miners and rescue team are out of mine	
Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	

Miscellaneous Comments	bodies. All five died from asphyxiation from low oxygen and high CO_2 levels. The first two fatalities may have survived with SCSRs which weren't available by 4/41978. It is unclear whether they would have had time to don SCSRs before being overcome. The one miner that died had called out that he was feeling dizzy before collapsing. The miners, however, had not suspected low oxygen or high CO_2 before the breakthrough. The other three fatalities were caused by would-be rescuers, including the MSHA Subdistrict Manager, entering a bad air environment without air supplies. The District Manager also entered twice without oxygen but was one of the lucky survivors. The fact that the mine was only a single entry being driven only 265 ft would have precluded any requirements for breathable air supplies or refuge stations.
Total number miners underground at the time of the accident	N/A – This accident is not applicable to the refuge station study
Number of miners impacted by the accident versus not impacted	N/A
Of those miners impacted, number immediately killed	N/A
Of those miners impacted, number that escaped and evacuated	N/A
Of those miners impacted, number that barricaded	N/A
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	N/A
Miners that escaped, escaped within what timeframe?	N/A
Miners that died, died within what timeframe?	N/A
Miners that were rescued, were rescued within what timeframe?	N/A

41. Jim Walters Resources, Incorporated, No. 4 Mine (ID No. 01-01247) March 10, 1996; Fatal Asphyxiation (1 Fatality)

This report is not directly applicable to refuge stations and is provided for information. It involves death by suffocation and thus was evaluated. It may be of use in specifying refuge stations for use in noxious atmospheres. The data is not included in the event tree analysis.

First indication of fire, explosion or inundation	CO detector being carried by victim alarmed at about 9:30 am March 10, 1996.
Death of Miner 1, Miner 2, …., etc.	Exact time of death of victim is not known but is assumed to be at or soon after 9:30 am.
First knowledge of accident outside mine	Exact time not in report (shortly after 12:10 pm March 10) – see next item below.
First knowledge of accident elsewhere inside mine	12:10 pm March 10 – The miner accompanying the victim at the time of the asphyxiation was also overcome at the same time for an undetermined amount of time. He regained consciousness and traveled to the longwall headgate to call for help.
Actions and movements of the miners inby (downstream) of fire or explosion.	N/A – Accident was a very localized asphyxiation over an area covered by an earlier rock fall.
Actions and movements of miners (outby) upstream of fire or explosion	N/A – Accident was a very localized asphyxiation over an area covered by an earlier rock fall.
Miners barricade	N/A
Rescue team enters mine	
Rescue team reaches miners	Time not reported – A recovery team of miners already within the mine longwall section returned to the accident scene (in the bleeder entries), recovered the victim and transported him out of the mine.
All miners and rescue team are out of mine	Time not reported – See above.
Distance of working section from surface of mine	Not known – N/A for this study.
Extent of flame	N/A – No explosion.
Extent of forces	N/A – No explosion.
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	N/A - Accident was a very localized asphyxiation over an area covered by an earlier rock fall. There was no need for any other miners in the mine to need to seek safety.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Data not available in report but N/A for this review.

Number of miners impacted by the accident versus not impacted	Only two in the area of the accident, both impacted.
Of those miners impacted, number immediately killed	One killed by irrespirable air (exact time after exposure not known).
Of those miners impacted, number that escaped and evacuated	One also overcome but regained consciousness and was able to crawl out of the area.
Of those miners impacted, number that barricaded	N/A
Number of barricaded miners rescued alive	N/A
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Two miners neutrally impacted (stations N/A).
Miners that escaped, escaped within what timeframe?	Miner who regained consciousness did so within an undisclosed time.
Miners that died, died within what timeframe?	Not reported (assume shortly after exposure to irrespirable air).
Miners that were rescued, were rescued within what timeframe?	N/A – No miners required rescue.

42. Grays Knob Coal Company, No. 5 Mine (ID No. 15-05184) June 3, 1981; CO_2 inundation (3 Fatalities)

This report is not directly applicable to refuge stations and is provided for information. It involved a significant number of deaths by suffocation and thus was evaluated. It may be of use in specifying refuge stations for use in noxious atmospheres. The data is not included in the event tree analysis.

First indication of fire, explosion or inundation	Summary report only available; brief narrative follows: At approximately 2:30 pm on 6/03/1981, the abandoned No. 1 Mine was inadvertently penetrated by the continuous miner operating in the No. 5 Mine. Contaminated air containing CO_2 and lacking oxygen rushed through the opening into the face. The entire section crew, except for two roof bolter operators who were in the entry adjacent to where the breakthrough occurred, boarded a scoop to ride to the surface via the mantrip route. The section foreman exited the mantrip to search for the missing bolter operators. All three perished and were found in the East Main Entries approximately 400 ft outby the face where the break though occurred. All died from asphyxiation.
Death of Miner 1, Miner 2, …., etc.	
First knowledge of accident outside mine	
First knowledge of accident elsewhere inside mine	
Actions and movements of the miners inby (downstream) of fire or explosion.	
Actions and movements of miners (outby) upstream of fire or explosion	
Miners barricade	
Rescue team enters mine	
Rescue team reaches miners	

All miners and rescue team are out of mine	No data on whether victims had, or attempted to use, self rescuers but it would not have mattered. Filter self rescuers, which were the type available in 1981, would have provided no protection against CO_2 or oxygen deficiency.
Distance of working section from surface of mine	
Extent of flame	
Extent of forces	
Would refuge stations have helped in this disaster? If so, WHY? If not, WHY NOT?	No – The miners were overcome quickly by bad atmosphere.
If stations were viable, would they have needed to be explosion-proof? If so, WHY? If not, WHY NOT?	N/A
If stations were viable, is there reason to believe that placement according to WV guidelines or coincident with locations for breathable air supplies per MSHA requirements would have worked? If so, WHY?	N/A
Miscellaneous Comments	None
Total number miners underground at the time of the accident	Not known – The summary report discusses only the miners in the affected section and does not provide the number of miners in that section.
Number of miners impacted by the accident versus not impacted	All miners in the affected section were impacted.
Of those miners impacted, number immediately killed	Not known – Two roof bolters did not gather with the other miners to escape and the timeframe of their deaths is not known (but they were likely overcome by asphyxiation quickly).
Of those miners impacted, number that escaped and evacuated	All except the two roof bolters began escape immediately and all made it to safety except for the foreman who left the escaping men to search for the roof bolters - he died in the process.
Of those miners impacted, number that barricaded	None attempted to barricade.
Number of barricaded miners rescued alive	None were rescued alive.
Number of barricaded miners that died	N/A
No. miners that could have been positively, negatively, neutrally affected by stations	Assume all neutrally affected: those that escaped did not need a station and the two roof bolters were probably killed too quickly to be able to reach one. *Possibility*: the section foreman, knowing that he was running into trouble while searching for the roof bolters, could have stopped and retreated to a station to regroup before either escaping or continuing his search for the other men.

Miners that escaped, escaped within what timeframe?	Not known; presumably very quickly.
Miners that died, died within what timeframe?	Not known; two were likely overcome by asphyxiation quickly; one was overcome some time later while searching for the two missing men.
Miners that were rescued, were rescued within what timeframe?	N/A – None were rescued.

Appendix B. Detailed Analyses of Selected Mine Disasters

This appendix presents detailed analyses of twelve mine disasters where it was determined that refuge stations would likely have saved miners' lives. These analyses examine the potential effect of refuge station location on miner survival.

1. Darby No. 1 Mine Explosion – May 20, 2006

1	Locations of victims with respect to working face area (if applicable)	Four miners (three of whom perished) were working in B Left Section, roughly 1,000 ft in by the explosion point (which was behind the seals of sealed-off adjacent A Left Section). The three victims had traveled about 1,400 to 1,800 from the B Left Section before they perished.
2	Location of victims if not associated with a working face area	The two victims working outby who initiated the explosion behind the seals of A Left were killed instantly by the force of the explosion.
3	Location of victims with respect to fire or explosion point of origin	The two victims killed instantly were right at the explosion point on the outby side of the seals that were destroyed. The other three victims had escaped from their section and were found in the Mains roughly opposite and about 300 ft away from the area of destroyed seals leading into the A Left Section.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	The four miners in B Left would have easily reached a station at 1,000 ft from the faces in the intake escapeway using SCSRs and a lifeline. As it was, they had traveled distances greater than 1,000 ft before they perished.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	Although the three victims from B Left had only traveled 1,400 to 1,800 ft from their section, the survivor had traveled nearly the full 2,000 ft to where a station at 2,000 ft from the faces might have been. With SCSRs and a lifeline, all four would have easily reached a station at 2,000 ft from the faces.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	None – a station at 2,000 ft from the faces would have held several advantages in this situation.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	The miners would have attempted escaped well beyond a station at 1,000 ft from the faces and would have either escaped entirely or would have easily reached a station at 2,000 ft from the faces. They would have needed to backtrack to a station at 1,000 ft from the faces. A station at 2,000 ft from the faces would have been subjected to significantly less force and would have been reached several hours sooner by rescuers than a station at 1,000 ft from the faces.
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO; no specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	None
10	Effect of FLAME on a station at 2,000 ft from the faces	None

11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	Details of forces were not provided. There were stoppings severely damaged in the immediate vicinity of a station at 1,000 ft from the faces, though forces to achieve this could have been as little as 2 to 4 psi. Forces several hundred feet away were as high as 20 psi., so it can be reasonably be expected that a station that could withstand 15 to 20 psi would survive in this location.
13	Effect of FORCES on a station at 2,000 ft from the faces	There was significantly less stopping damage in this location indicating that forces were likely less than 2 to 4 psi.
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Rescuers would have likely reached a station at 1,000 ft from the faces within 8 to 10 hr and a station at 2,000 ft from the faces within 3 hr after the explosion.
16	Would additional outby stations have been beneficial?	No; if the miners had been able to escape the immediate area somewhat beyond where a station at 2,000 ft from the faces would have been located, they could have made it safely to clean air.

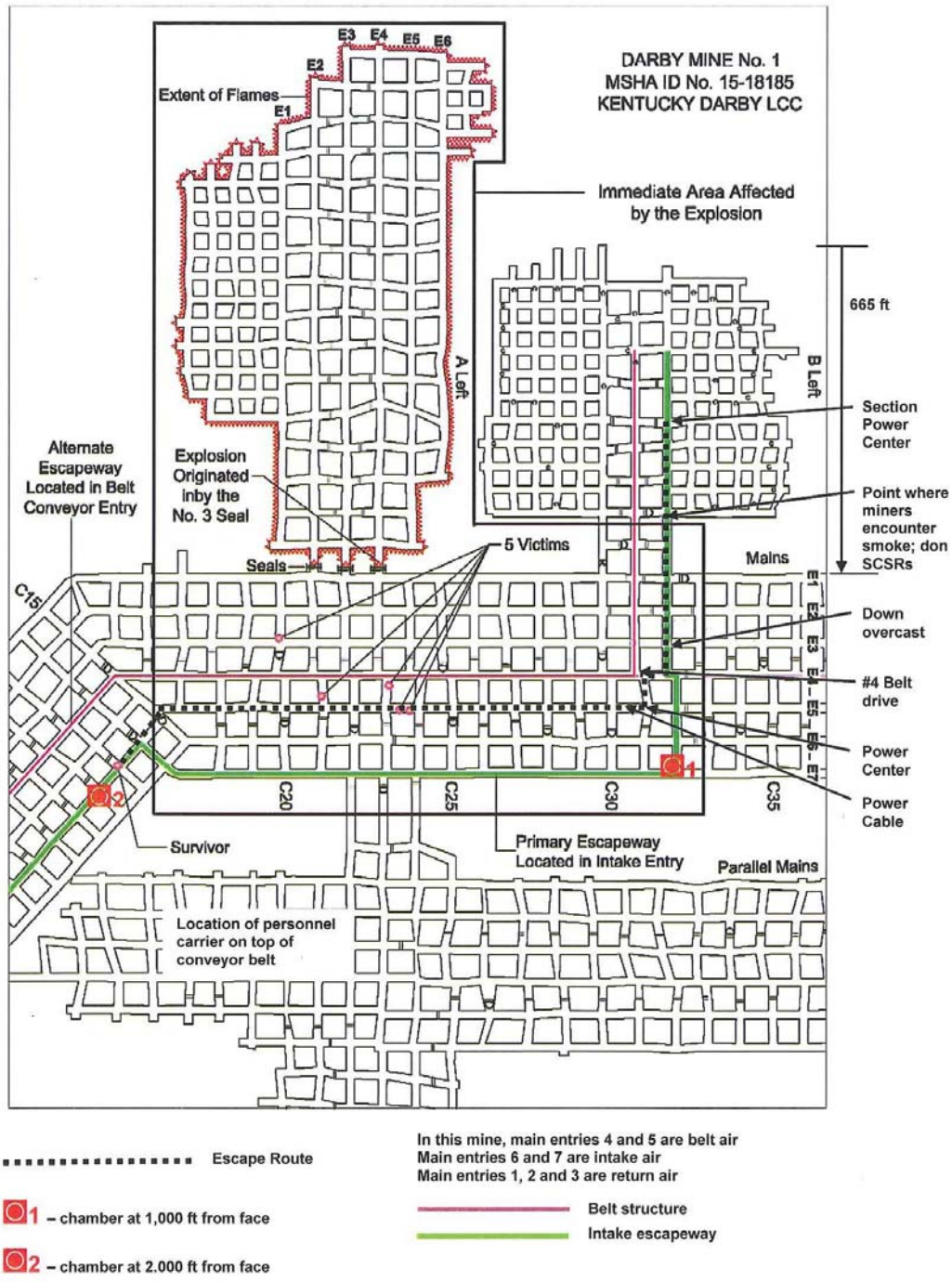

Figure B-1. Darby mine map

Conclusions from the Darby Disaster

- The explosion did not occur at a coal producing working face but rather about 1,000 ft outby behind a sealed off adjacent section. Two of the victims (killed instantly) were right at the point of origin because they ignited gas behind the seals.

- Stations at 1,000 ft or 2,000 ft from the faces would have been easily reachable by the miners from B Left section using SCSRs and lifelines. However, the location at 2,000 ft would have been preferable because the miners had already made it that far in their escape attempt, a station at 2,000 ft would have been subjected to significantly less force and rescuers would have reached it several hours sooner.

- Flames would not have affected either a station at 1,000 ft or 2,000 ft from the faces. However, forces up to 15 to 20 psi would have impacted a station at 1,000 ft from the faces and forces of about 2 to 4 psi or less would have impacted a station at 2,000 ft from the faces.

- Rescue teams would have likely reached a station at 1,000 ft from the faces within 8 to 10 hr and a station at 2,000 ft from the faces within 3 hr after the explosion.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

2. Aracoma Alma No. 1 Mine Fire – January 19, 2006

1	Locations of victims with respect to working face area (if applicable)	The No. 2 Section crew was in their working faces when the fire started
2	Location of victims if not associated with a working face area	N/A
3	Location of victims with respect to fire or explosion point of origin	The fire occurred at the No. 9 Headgate longwall belt storage, about 3,500 ft outby the working faces. The fire was located one entry off the intake escapeway but smoke contaminated the escapeway due to a removed stopping.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	Yes, easily. A station at 1,000 ft from the faces would have been about 1,000 ft inby where the retreating miners first encountered heavy smoke, so they would have bypassed it initially but could have easily returned to it if they needed to after encountering the heavy smoke.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	Yes, easily. A station at 2,000 ft from the faces would have been quite close to where the retreating miners first encountered heavy smoke, so they could have either entered it at that point or bypassed it initially in favor of a full escape. Again, they could have easily returned to it if they needed to after encountering the heavy smoke.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	None in this case – either station would have been easily reachable by the retreating miners and neither would have been more likely than the other to be affected by flames or heat from the fire.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	Either station would have been easily reachable by the retreating miners. A station at 2,000 ft from the faces would have been reached slightly sooner by rescue crews than a station at 1,000 ft from the faces due to its location further outby
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO; no specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	None
10	Effect of FLAME on a station at 2,000 ft from the faces	None
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	N/A - this was a fire with no forces applicable
13	Effect of FORCES on a station at 2,000 ft from the faces	N/A - this was a fire with no forces applicable
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	A station at 2,000 ft from the faces would have been reached slightly sooner by rescue crews than a station at 1,000 ft from the faces due to its location further outby but either station would have been reached within 48 hr (probably much less).
16	Would additional outby stations have been beneficial?	No; if the victims had been able to escape the immediate area beyond where a station at 2,000 ft from the faces would have been located, they eventually would have made it safely to clean air (as did the miners that successfully escaped).

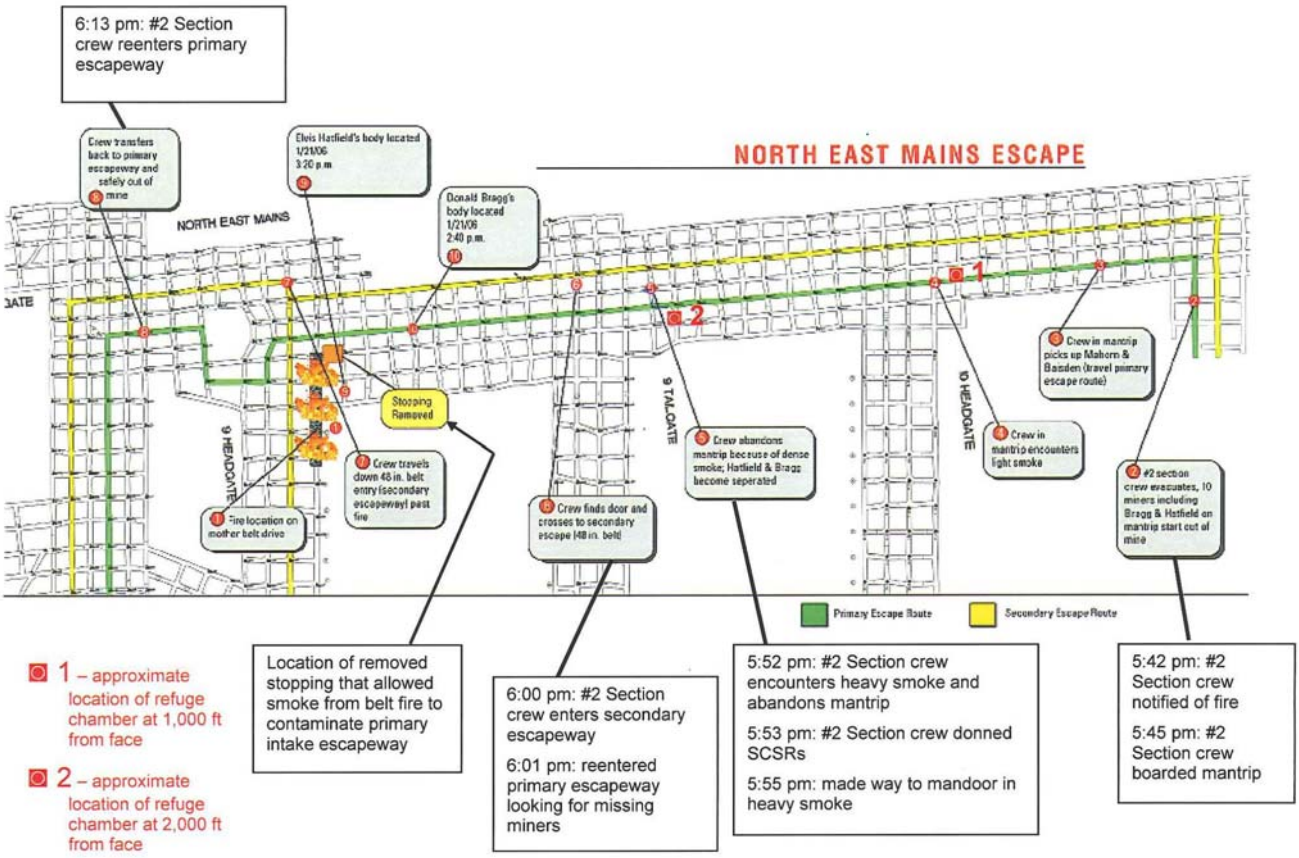

Figure B-2. Alma mine map

Conclusions from the Alma No. 1 Mine Disaster

- A station at 1,000 ft or 2,000 ft from the faces would have been easily reachable by the victims using SCSRs and lifelines. Rescue teams would have reached them at either station within 48 hr (and possibly much sooner).

- Neither a station at 1,000 ft nor 2,000 ft from the faces would have been directly affected by flames or heat. There is no significant reason that either a station at 1,000 ft or 2,000 ft from the faces would have been preferred in this situation.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

- As with the Wilberg fire, the Alma fire was associated with a conveyor belt system. This again confirms the suggestion stations never be located within escapeway crosscuts that are close to belt drives or other potential fire hot spots.

3. Sago Mine Explosion – January 2, 2006

1	Locations of victims with respect to working face area (if applicable)	Eleven victims were located within the 2nd Left Parallel section near the faces.
2	Location of victims if not associated with a working face area	The 12th victim was found in the track entry of the 2 North Mains about 450 ft outby the seals that were destroyed in the explosion.
3	Location of victims with respect to fire or explosion point of origin	The explosion occurred at the seals that sealed off the 2nd Left Mains, about 2,200 to 2,300 outby the 2nd Left Parallel section within the 2 North Mains.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	Yes, easily for all 12 victims. In fact, the station would have been slightly inby where the miners abandoned their mantrip to begin a walking escape. Once they decided escape was not possible, they would have easily retreated to a station at 1,000 ft from the faces (in lieu of barricading as in the actual disaster).
5	Would victims have been able to reach a station at 2,000 ft from the faces?	A station at 2,000 ft from the faces would have been easily reachable by the 12th victim who was within the 2 North Mains (it would have been 3 crosscuts outby his position). The 11 victims within the 2nd Left Parallel section, however, would have had a much more difficult time reaching the station at 2,000 ft due to smoke and debris. The current regulations requiring each miner to have a second self-rescuer, requiring tethers to keep the crew together, and a lifeline to guide them would have improved the chances of a successful escape to a station at 2,000 ft from the faces.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	As noted above, the station at 1,000 ft from the faces would have been within the working section, out of the direct line of fire of the explosion and easily reachable by all victims.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	None – The station at 2,000 ft from the faces in this situation would have been out in the 2 North Mains in the line of fire of the explosion (though forces would have been low) and more difficult for the miners within the 2nd Left Parallel section to reach due to smoke and debris.
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO – No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	None – Flame was confined almost entirely to the sealed area of 2nd Left Mains and extended only about 200 ft outby the damaged seals.
10	Effect of FLAME on a station at 2,000 ft from the faces	None – Flame was confined almost entirely to the sealed area of 2nd Left Mains and extended only about 200 ft outby the damaged seals.
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	Forces about 550 ft outby the seals were less than 5 psi. One victim of CO poisoning was found in the track entry about 550 ft outby the seals with no evidence of blunt force trauma. Forces at the face of the 2nd Left Parallel Section were estimated at 2 psi. Hence forces on a station at 1,000 ft from the faces would have been somewhere between 2 psi and 5 psi.

13	Effect of FORCES on a station at 2,000 ft from the faces	A station at 2,000 ft from the faces would have been located about 3 crosscuts outby where the victim was found about 550 ft outby the seals. Forces on a station at 2,000 ft from the faces would have been somewhere between 2 psi and 5 psi.
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Rescuers would have easily reached a station at 2,000 ft from the faces within about 40 hr and a station at 1,000 ft from the faces within about 48 hr after the explosion based on the timeline of actual events.
16	Would additional outby stations have been beneficial?	Doubtful; it would have been difficult for the miners from 2nd Left Parallel section to make it to a station at 2,000 ft from the faces let alone to a further outby station.

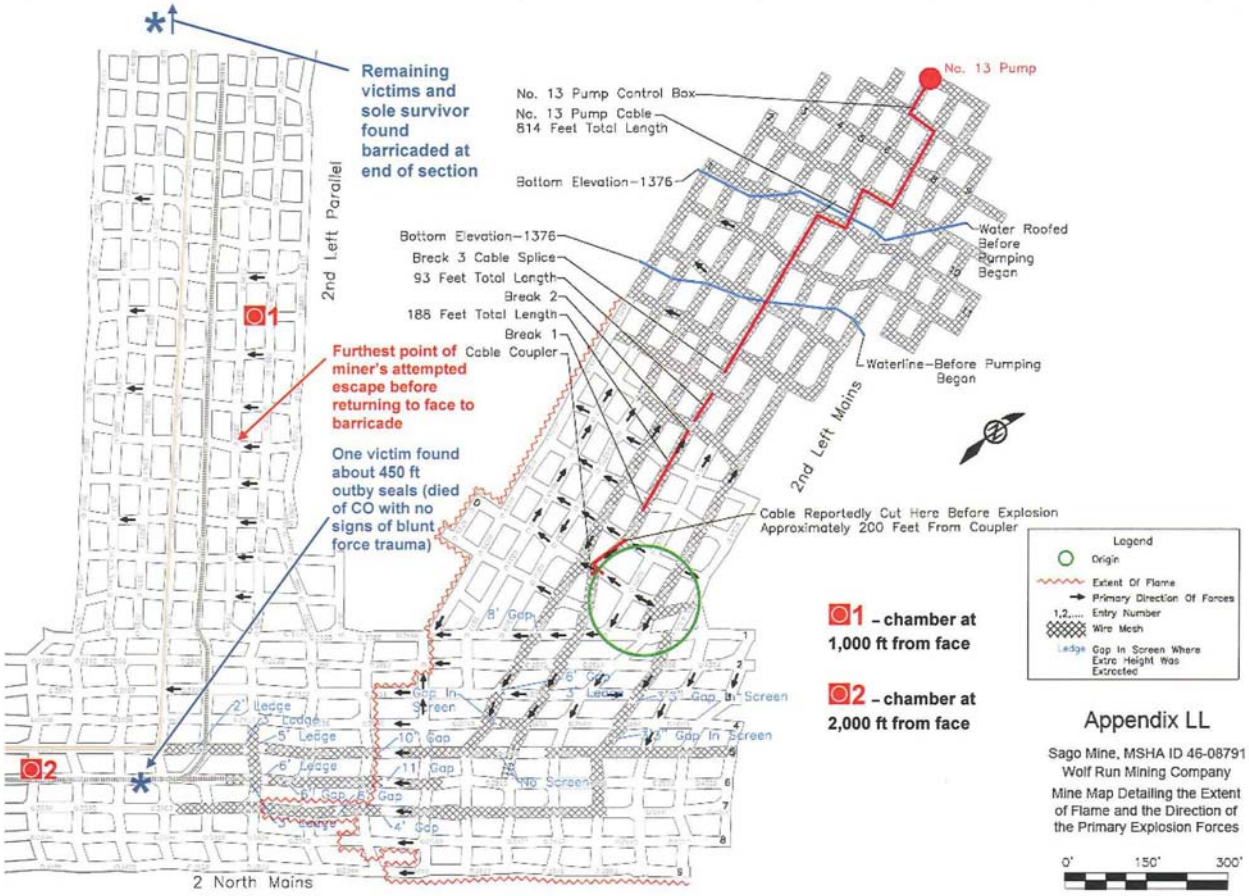

Figure B-3. Sago mine map

Conclusions from the Sago Disaster

- The explosion did not occur at a working face but rather at the seals that sealed off the 2nd Left Mains, about 2,200 to 2,300 outby the 2nd Left Parallel section where men were working.

- A station at 1,000 ft from the faces would have been easily reachable by all 12 miners affected by the explosion using SCSRs and lifelines. It would have been within the working section out of the direct line of fire of the explosion. Rescue teams would have reached them at the station within 48 hr.

- A station at 2,000 ft from the faces would have been much more difficult for the miners to reach due to smoke and debris and would have been in the line of fire of the explosion. The station at 1,000 ft from the faces would have been preferred in this situation.

- Neither a station at 1,000 ft nor 2,000 ft from the faces would have been impacted by flames but both would have been impacted by forces in the range of 2 to 5 psi.

- As with the analysis of the Scotia disaster, the Sago disaster shows the benefits of a station located some distance inside the working section away from the junction with the mains, providing protection from explosions occurring in the main entries.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

4. Pyro William Station Mine Explosion – September 13, 1989

1	Locations of victims with respect to working face area (if applicable)	Coal was not being mined in this case but equipment on a completed longwall panel was being recovered. Four of the victims (likely killed instantly) were located right on the face; the other six victims were located in the No. 3 recovery room about 250 ft outby the face.
2	Location of victims if not associated with a working face area	See above.
3	Location of victims with respect to fire or explosion point of origin	It is not certain where the explosion originated, though it most likely originated in the center entry (E2) of the 3 entries adjacent to the mined out longwall panel. This would have been about 450 ft inby the location of the four victims at the face and about 1,000 ft inby the six victims in the No. 3 recovery room.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	The location of a station at 1,000 ft from the faces for this situation is difficult to pinpoint. The panel had finished mining and face equipment was being recovered and moved to the next adjacent panel to be mined. If a portable station would have been moved outby with each 1000 ft of advance, the final location for finishing the panel and panel recovery would have likely been in the 1st Main North Track entry, just outside the range of flame or forces. Lifelines would have clearly aided miners and would have likely prevented at least four fatalities.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	Locating a station at 2,000 ft from the faces would follow the same logic. It would also likely be in the 1st Main North Track Entry 1,000 ft further outby and in fresh air. It is unclear whether miners reaching a station at this location would have stopped to recuperate and regroup or would have continued their escape to the outside.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	The report indicates that some of the six victims not killed instantly were severely injured, others appeared to become disoriented in the heat and smoke, and others removed their FSR's to communicate or help others and were overcome by smoke and CO. Hence it is likely that the closer station at 1,000 ft from the faces would have given them a significantly greater chance of survival than a station at 2,000 ft from the faces further outby.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	None – See above. Neither a station at 1,000 ft from the faces nor a station at 2,000 ft from the faces would have been subjected to significant flame, heat or forces.
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO – No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	A station at 1,000 ft from the faces would have been just outside the zone of flame impact.
10	Effect of FLAME on a station at 2,000 ft from the faces	A station at 2,000 ft from the faces would have been well outside the zone of flame impact and in fresh air.
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	A station at 1,000 ft from the faces would have been outside the zone of forces as evidenced by the lack of damage to ventilation stoppings at the location.
13	Effect of FORCES on a station at 2,000 ft from the faces	None (well outby the zone of forces)
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Attempts to rescue and recover victims started almost immediately by survivors of the crew and by others underground who traveled to their location. There is no timeline for these efforts. Official rescue and recovery teams arrived and entered the mine by 12:23 pm. By this time, slightly more than 3 hr after the explosion, all victims had been recovered.
16	Would additional outby stations have been beneficial?	No – If the miners had been able to escape the immediate area somewhat beyond where a station at 1,000 ft from the faces would have been located, they could have made it safely to clean air.

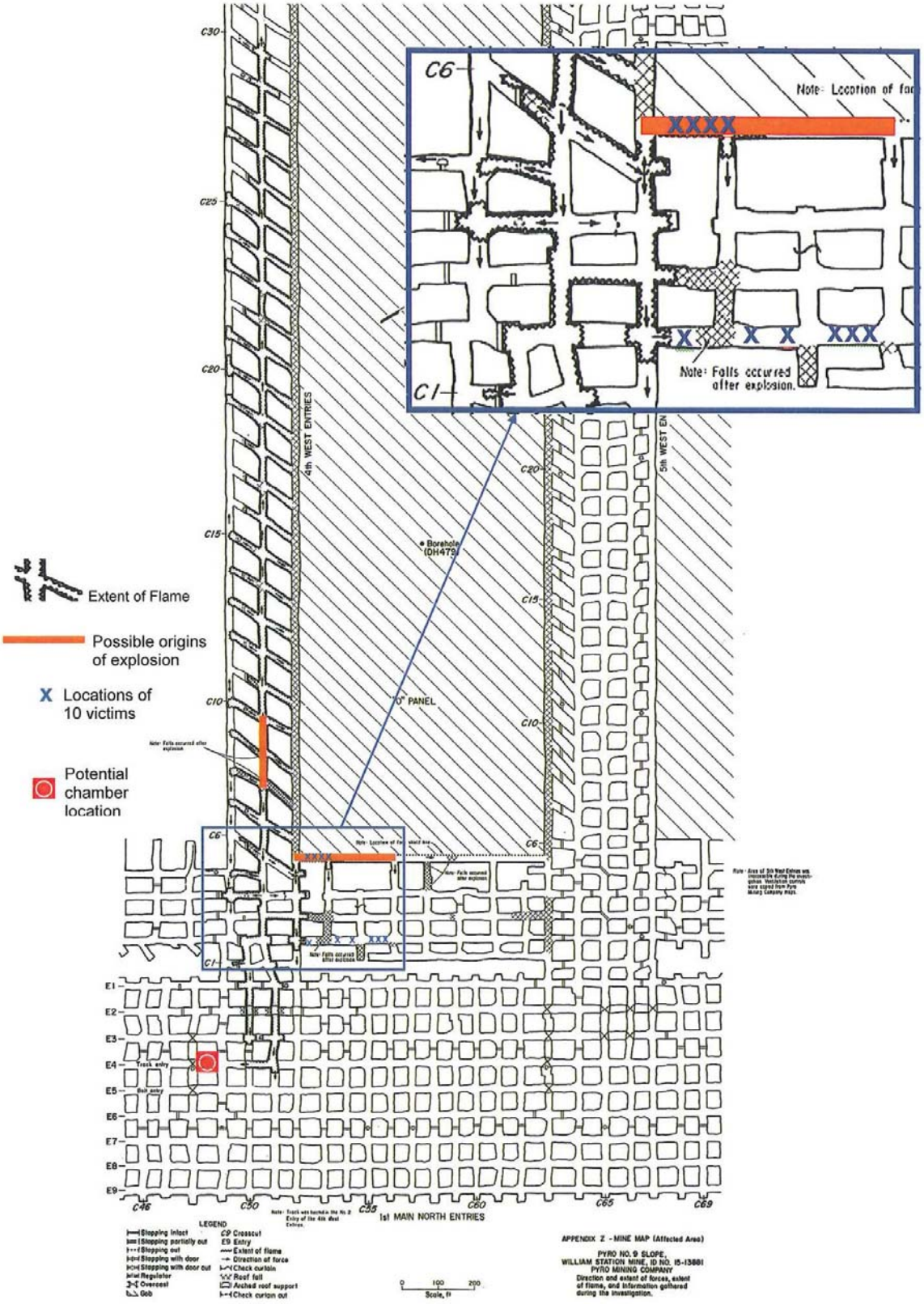

Figure B-4. Pyro No. 9 slope (William Station Mine) mine map

Conclusions from the Pyro William Station Disaster

- Coal was not being mined in this case but equipment on a completed longwall panel was being recovered. It is not certain where the explosion originated, though it was most likely in the center entry of the 3 entries adjacent to the mined out longwall panel about 450 ft inby the longwall face.

- A station at 1,000 ft from the faces guidelines would have been reachable by at least four of the miners affected by the explosion using SCSRs and lifelines. Rescue teams would have reached them at the station within 3 hr (and possibly sooner).

- A station at 2,000 ft from the faces may also have been reachable by four of the miners and would have been in fresh air. However, given the potential injury and disorientation of the miners, the closer station at 1,000 ft from the faces would have given them a better chance of survival.

- Neither a station at 1,000 ft nor 2,000 ft from the faces would have been subjected to flame or explosion forces.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

5. Wilberg Mine Fire – December 19, 1984

1	Locations of victims with respect to working face area (if applicable)	• Thirteen victims from 1,500 to 1,900 ft from the longwall face: nine in the "dogleg" and four in the belt entry • ten victims were in the headgate (outby) at or within 200 ft of the longwall face • Three victims were in the tailgate entry (outby) within 400 ft of the longwall face • One victim was located in the bleeder entries a considerable distance from the longwall face
2	Location of victims if not associated with a working face area	N/A
3	Location of victims with respect to fire or explosion point of origin	The fire source was about 2,200 ft outby the longwall face in the same direction that most of the miners had traveled, so 13 victims were within 300 to 700 ft of the fire; 10 victims in the headgate were about 2,000 ft from the fire; the remaining victims in the tailgate and bleeders were well away from the fire
4	Would victims have been able to reach a station at 1,000 ft from the faces?	YES – They passed the location of a station at 1,000 ft from the faces in their attempts to escape and would have easily been able to retreat back to it.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	YES – They ended up advancing to very near where a station at 2,000 ft from the faces would have been located. However, a station at 2,000 ft would have been located quite near the fire source and (though not directly affected by flames) might have been very hot.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	In this case a station at 1,000 ft from the faces would have been safer due to its location considerably further from the source of the fire. Either station would have been readily reachable by the miners.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	N/A – See above
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO – No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	N/A
10	Effect of FLAME on a station at 2,000 ft from the faces	N/A – Though heat may have been a negative factor
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	N/A – This was a fire with no forces applicable
13	Effect of FORCES on a station at 2,000 ft from the faces	N/A – This was a fire with no forces applicable
14	Effect of FORCES on a station per OTHER guidelines	N/A – This was a fire with no forces applicable
15	Time that rescuers would have made contact with trapped miners	Difficult to be certain (see report text); it's possible that mine personnel might have been able to reach miner's trapped in a station within 2 hr; failing that, rescue teams with oxygen should have been able to reach them within 14 hr, though the fire began to burn out of control at that point; the worst case scenario would have been at 32.5 hr (when rescue teams first reached the victims after the fire was brought back into control)
16	Would additional outby stations have been beneficial?	No – If the miners had been able to escape the immediate area somewhat beyond where a station at 2,000 ft from the faces would have been located, they could have made it safely to clean air.

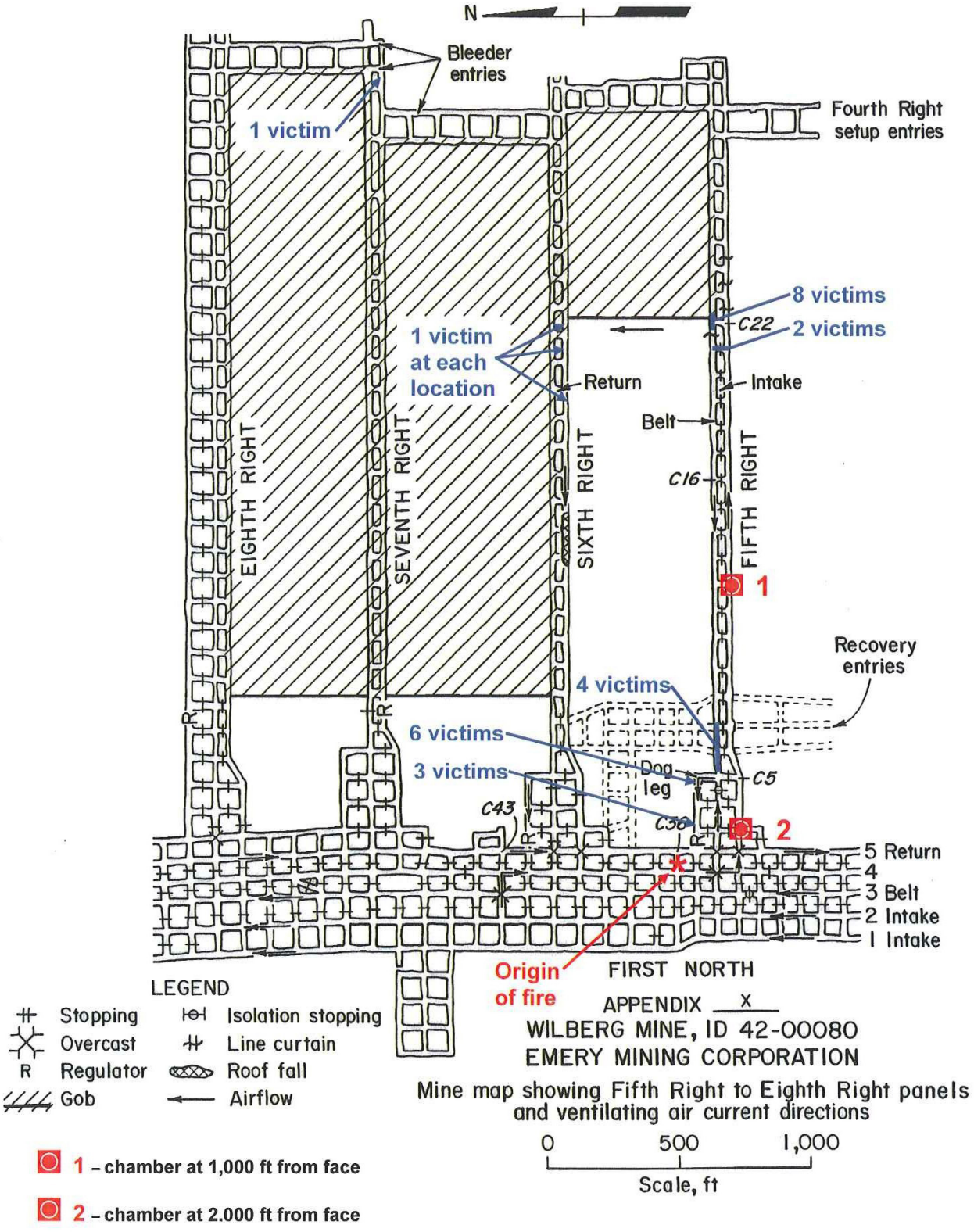

Figure B-5. Wilberg map

Conclusions from the Wilberg Disaster

- A station at 1,000 ft from the faces would have been easily reachable by all miners affected by the fire using SCSRs and lifelines. Rescue teams would have reached them at the station within 32.5 hr (and possibly much sooner). A station at 1,000 ft from the faces would not have been affected by flame.

- A station at 2,000 ft from the faces would also have been easily reachable by all miners but would have been much closer to the source of the fire. Although not directly affected by flames, it could have been affected by heat. The station at 1,000 ft from the faces location would have been preferred in this situation.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

- Conveyor belt systems, especially belt drives, are potential friction hot spots and have been sources of mine fires in the past. A recommendation for station positioning is to avoid locating them 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.

6. Scotia Mine Explosion – March 9 and 11, 1976

1	Locations of victims with respect to working face area (if applicable)	*March 9*: 13 of 15 victims in or near entrance of 2 Left off 2 Southeast Main and two victims in 2 Southeast Main inby 2 Left *One victim* at No. 22 crosscut, No. 2 entry, 2 Southeast Main + *three victims* in Nos. 1 and 2 entries, 2 Southeast Mains near entrance to 2 Left + *three victims* along No. 4 entry in 2 Left + *six victims* behind partial barricade in No. 5 entry of 2 Left Also….*two victims* at explosion point between crosscuts 31 and 32 in entry No. 4 of Southeast Main (about 800 ft inby the working faces of 2 Left)
2	Location of victims if not associated with a working face area	*March 11*: all 11 victims were outby in Left Panel of Northeast Main in-line with the explosion that occurred inby within or near the entrance to 2 Left off 2 Southeast Main Two additional miners in Left Panel located nearby but just away from the direct line of the explosion escaped uninjured
3	Location of victims with respect to fire or explosion point of origin	*March 9*: 13 victims at working section about 800 ft outby the explosion point (which occurred inby); two victims right at the explosion point *March 11*: all 11 victims (and two survivors) were about 2,500 ft outby the explosion point
4	Would victims have been able to reach a station at 1,000 ft from the faces?	*March 9*: it appears likely that at least the 6 barricaded victims (and possibly also the three other victims within 2 Left) would have been able to reach either a station at 1,000 ft or 2,000 ft from the faces. The other 6 victims were likely injured too severely to attempt to reach a station. *March 11*: all victims were well outby either stations at 1,000 ft or 2,000 ft from the faces, so only outby stations would be relevant. In any event, injuries to all victims appeared too severe for any of them to attempt to reach any station.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	*March 9*: a station at 1,000 ft from the faces would have been better only IF some of the 9 victims for whom a station might have helped were injured or overcome sufficiently to need the closer-in location (the report does not discuss their condition in detail). *March 11*: N/A
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	*March 9*: because the explosion occurred inby, the flame would have impacted a station at 1,000 ft from the faces but not a station at 2,000 ft from the faces. Also, forces (already minimal) might have impacted a station at 2,000 ft from the faces less. *March 11*: N/A
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	*March 9*: because of the unusual location of the explosion inby and somewhat away from the working section, a station 200 ft or so inside 2 Left away from the junction with 2 Southeast Main would have been protected from the flame and explosion forces and very accessible to the miners. However, location strategies for unusual situations can't be predicted ahead of time and locations at 1,000 ft or 2,000 ft from the faces seem reasonable. *March 11*: in this case, stations would probably not have helped due to the severe injuries to the victims. However, if some injured victims had survived, though only enough to search for a station, this explosion shows the viability of maintaining outby stations each 1 hr travel time.
9	Effect of FLAME on a station at 1,000 ft from the faces	*March 9*: flame *would* have affected a station per at 1,000 ft from the faces guidelines (though details of the severity of the flame are not known)

10	Effect of FLAME on a station at 2,000 ft from the faces	*March 9*: flame *would not* have affected a station at 2,000 ft from the faces *March 11*: flame would likely *not* have affected outby stations at 1 hr travel distances.
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	*March 9*: forces would have affected a station at both 1,000 ft and 2,000 ft from the faces, though potentially somewhat more to the closer station at 1,000 ft from the faces *March 11*: forces would likely *not* have affected outby stations at 1 hr travel distances.
13	Effect of FORCES on a station at 2,000 ft from the faces	
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	*March 9*: potentially minutes after the explosion to a station at 2,000 ft from the faces; 10+ hr to a station at 1,000 ft from the faces, *March 11*: about 12 to 13 hr after the explosion
16	Would additional outby stations have been beneficial?	No, but as noted above for the March 11 explosion, if some injured victims had survived, though only enough to search for a station, this explosion shows the viability of maintaining outby stations each 1 hr travel time.

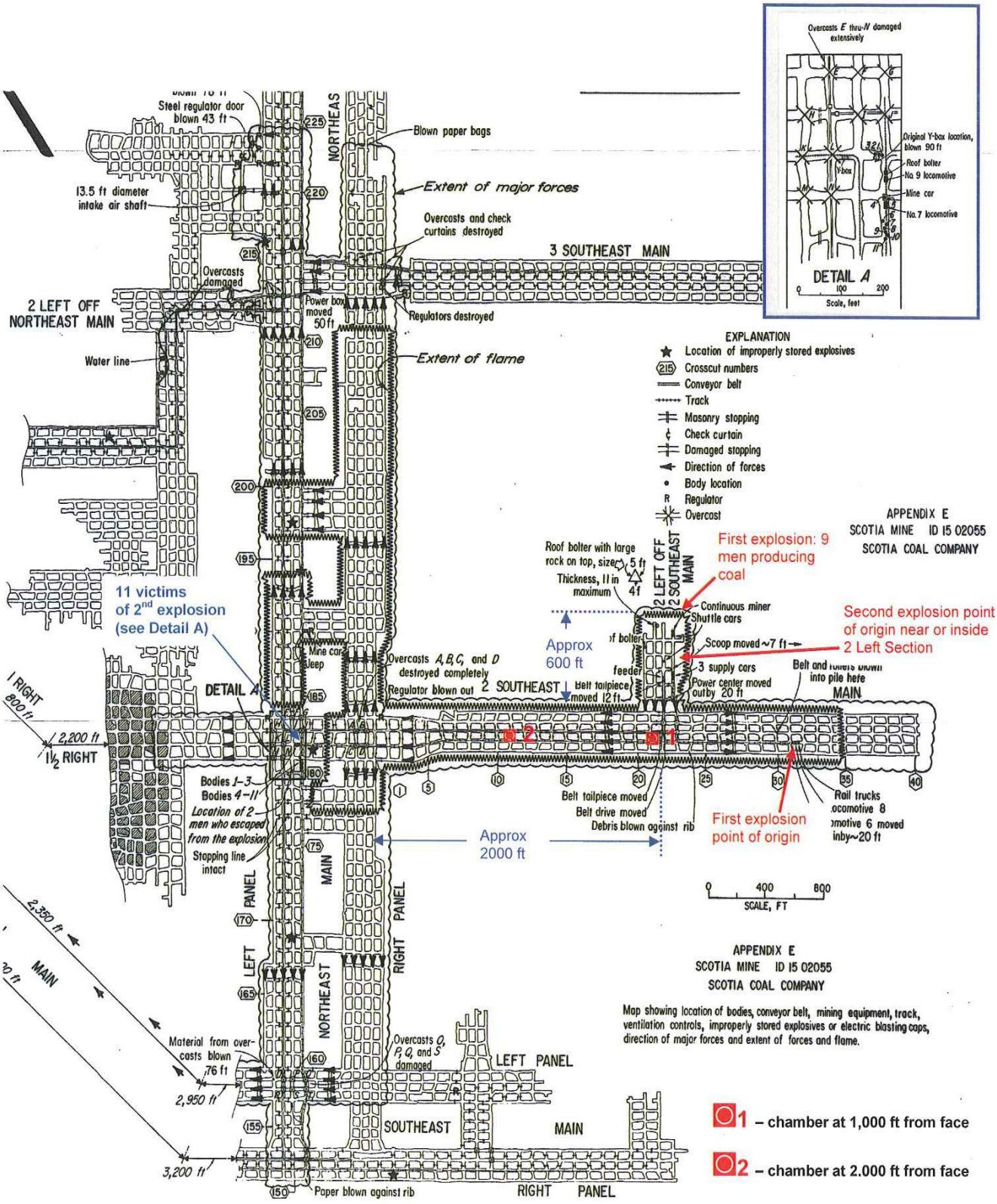

Figure B-6. Scotia mine map

Conclusions from the Scotia Disaster

- Neither the March 9 nor March 11 explosions occurred at the working sections. The March 9 explosion originated within the main entries about 800 ft inby the coal producing section off the mains. The March 11 explosion originated about 2,500 ft inby the location of the victims (who were working at an outby location).

- A station at 1,000 ft from the faces would likely have been reachable by at least nine miners affected by the March 9 explosion using SCSRs and lifelines. Rescue teams would have reached them at the station within 10+ hr. A station at 1,000 ft from the faces *would* have been affected by flames.

- A station at 2,000 ft from the faces should also have been reachable by the nine miners affected by the March 9 explosion (as long as they were not so severely injured as to be unable to travel the extra distance). Rescue teams would have reached them at the station within minutes. A station at 2,000 ft from the faces would *not* have been affected by flames.

- Both a station at 1,000 ft and 2,000 ft from the faces would have been affected by forces of the March 9 explosion; the closer station at 1,000 ft from the faces would likely have been subjected to somewhat higher forces.

- A station at 2,000 ft from the faces would have been the preferred location in the case of the March 9 explosion (unless the miners were injured so severely as to not be able to reach it). It would have been subjected to lesser explosion forces, would not have been impacted by flame and would likely have been reached much sooner by rescuers.

- All victims of the March 11 explosion likely died instantly or soon after the explosion and were probably too injured to reach any station. In any event, a station at 1,000 ft or 2,000 ft from the faces would have been located well inby the positions of the victims and not applicable. This is a case where, if the details of the explosion had been different, only outby stations could have helped the miners.

- Regarding possible station locations for working sections other than as specified at 1,000 ft or 2,000 ft from the faces, the March 9 Scotia disaster was similar to the Sago disaster in that miners within a working section off main entries were trapped inside their sections due to an explosion that occurred out in the main entries inby their location. In these cases, it would have been preferable to maintain a refuge station some distance inside their sections 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. Other than that, no specific rationale for a station location different from either at 1,000 ft or 2,000 ft from the faces surfaced in this study.

7. Oakwood Red Ash No. 4 Mine Explosion – September 25, 1973

1	Locations of victims with respect to working face area (if applicable)	N/A – See below
2	Location of victims if not associated with a working face area	The two men affected by the explosion were traveling in an abandoned section of the mine to look for abandoned mining equipment and examine the area; the active working areas were 6,000 ft away (not relevant to the explosion).
3	Location of victims with respect to fire or explosion point of origin	The two victims were right at the point of origin because the vehicle they were traveling in ignited gas.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	It is likely that if a station had existed in the area before it had been mined out, it would have been relocated and so not available to the victim. If, however, a station had remained, if the men had been able to don and use SCSRs and if the extent of their injuries had not been too severe, they would have likely been able to reach a station at 1,000 ft from the faces.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	Ditto the discussion for stations at 1,000 ft from the faces above. Since the report doesn't discuss the extent of injuries to the victims, it is not possible to speculate on whether the miners could have reached either a station at 1,000 ft or 2,000 ft from the faces.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	If a station at 1,000 ft from the faces had remained in the abandoned area, it would have been much closer to the victims than a station at 2,000 ft from the faces. This could have been important depending on the extent of injuries to the victims.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	If a station at 2,000 ft from the faces had remained in the abandoned area, it would have been further away and so would have *not* been subjected to the flame from the explosion whereas a station at 1,000 ft from the faces would have. Both stations would have been subjected to the forces of the explosion, though the forces were minimal (and would have likely impacted a station at 2,000 ft from the faces even less than a station at 1,000 ft from the faces).
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	N/A since the explosion occurred well away from active working areas.
9	Effect of FLAME on a station at 1,000 ft from the faces	Flame *would* have impacted a station at 1,000 ft from the faces
10	Effect of FLAME on a station at 2,000 ft from the faces	Flame *would not* have impacted a station at 2,000 ft from the faces
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	Forces *would* have impacted a station at 1,000 ft from the faces, though forces were minimal
13	Effect of FORCES on a station at 2,000 ft from the faces	Forces *would* have impacted a station at 2,000 ft from the faces, though forces were minimal. In any event, they would have likely impacted a station at 2,000 ft from the faces even less than a station at 1,000 ft from the faces.
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Within less than 21 hr (had a station existed in the area)
16	Would additional outby stations have been beneficial?	Doubtful, since an outby station would have likely been located well away from the abandoned area. Since the report doesn't discuss the extent of injuries to the victims, it is not possible to speculate on whether the miners could have reached an outby station.

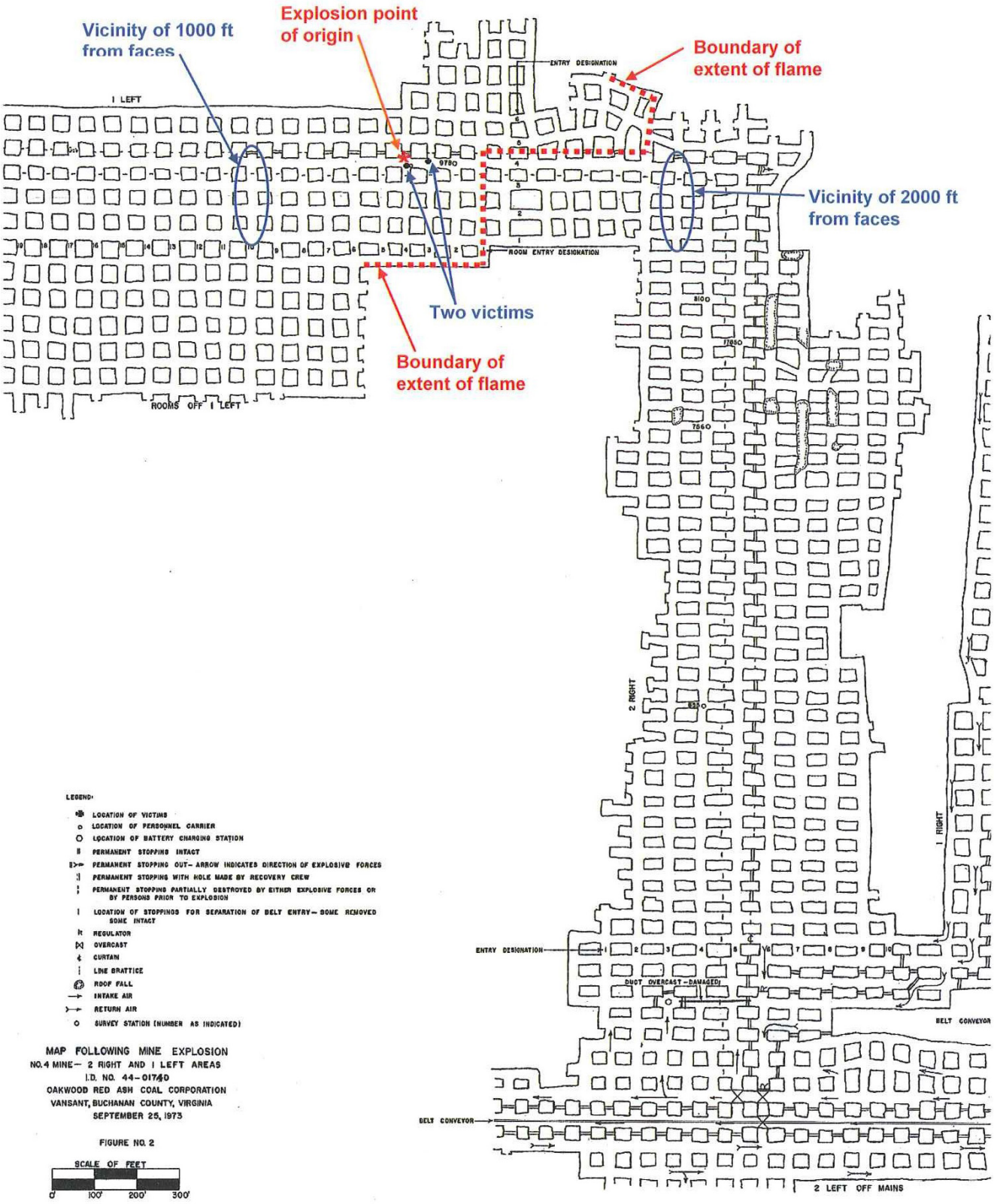

Figure B-7. Oakwood Red Ash No. 4 mine map

Conclusions from the Oakwood Red Ash No. 4 Mine Disaster

- The explosion did not occur at a coal producing working face but rather in an abandoned area of the mine where two miners were searching for abandoned mining equipment. They were right at the point of origin because the vehicle they were traveling in ignited gas.

- Stations at 1,000 ft or 2,000 ft from the faces would likely not have existed any longer in this area of the mine and so would not have been applicable in this case. If, however, a station had remained, if the men had been able to don and use SCSRs and if the extent of their injuries had not been too severe, they would have likely been able to reach either a station at 1,000 ft or 2,000 ft from the faces (or an outby station if one had been located in the vicinity).

- If a station at 1,000 ft from the faces had remained in the area, it would have been impacted by both flame and forces (though forces would have been minimal). A station at 2,000 ft from the faces would not have been impacted by flame but would have been impacted minimally by forces.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study.

- This disaster suggests that it could be important to maintain stations either at 1,000 ft or 2,000 ft from the faces for abandoned or mined out areas of mines as long as there is likelihood that miners will still need to access those areas, particularly since they may not be as well ventilated as more active working sections.

8. Itmann No. 3 Mine Explosion – December 16, 1972

1	Locations of victims with respect to working face area (if applicable)	All eight miners affected (five killed and three injured) were traveling out of the mine on a mantrip at shift's end and were about 1,000 ft away from their working faces when a dislodged trolley pole on their mantrip caused the explosion.
2	Location of victims if not associated with a working face area	N/A
3	Location of victims with respect to fire or explosion point of origin	All eight affected miners were right at the point of the explosion.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	By coincidence only, the explosion occurred at a point about 1,000 ft from the faces and so very nearby a potential location of a station at 1,000 ft from the faces. Given this fact and the severe injuries of the three miners not killed instantly, it is assumed that two of the injured miners probably would have been able to reach a station if it had been clearly marked. The third injured miner appeared too severely injured to have made it to a station even close by.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	No, given the severity of their injuries it is unlikely that any of the three injured miners could have traveled the approximate 1,000 ft to a station at 2,000 ft from the faces.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	A station at 1,000 ft from the faces would have been adjacent to the injured miners. However, this was a coincidence and the explosion could have occurred just as easily next to a station at 2,000 ft from the faces, or to some other location not near a station at all.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	None – A station at 2,000 ft from the faces would have been too far away to help the severely injured miners.
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO – No specific rationale for a station location different from either at 1,000 ft or 2,000 ft from the faces surfaced in this study given the impossibility of predicting where a random explosion might occur in a case such as this.
9	Effect of FLAME on a station at 1,000 ft from the faces	Flame extended about 650 ft inby and outby the site of the explosion in the intake track entry and lesser distances in the adjacent intake entry. It would have impacted a nearby station at 1,000 ft from the faces with temperatures likely less than 450°F.
10	Effect of FLAME on a station at 2,000 ft from the faces	Flame would not have reached a station at 2,000 ft from the faces in this instance.
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	There was stopping damage in the immediate vicinity of the explosion. The lack of physical trauma on the victims and the limited extent of stopping damage would indicate forces in the 2 to 4 psi range at a station at 1,000 ft from the faces.
13	Effect of FORCES on a station at 2,000 ft from the faces	There was minimal stopping damage at the location of a station at 2,000 ft from the faces, indicating pressures of less than 2 psi.
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Rescuers would have reached a station at 2,000 ft from the faces within 4 1/2 hr and a station at 1,000 ft from the faces within 5 hr after the explosion.
16	Would additional outby stations have been beneficial?	No; given the extent of their injuries, the miners would not have been able to make it to an outby station.

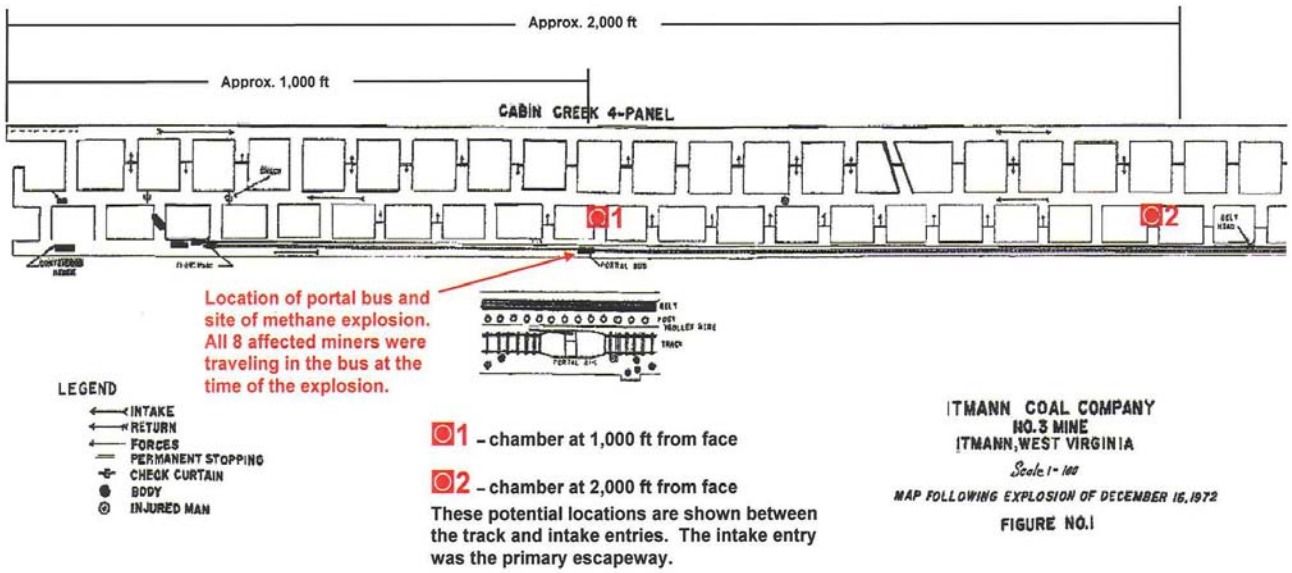

Figure B-8. Itmann No. 3 mine map

Conclusions from the Itmann Disaster

- The explosion did not occur at a coal producing working face but rather along the travelway from the face out of the section (at a point about 1,000 ft outby the face). All miners affected by the explosion were right at the point of the explosion because a dislodged trolley pole on their mantrip caused it.

- By coincidence only, the explosion occurred at a point about 1,000 ft from the faces and so very nearby a potential location of a station at 1,000 ft from the faces. Given the severe injuries of the three miners not killed instantly, it is assumed that two of them may have been able to reach the station. The third injured miner appeared too severely injured to have made it to the station. None of the miners would have been able to reach a station at 2,000 ft from the faces. Rescue teams would have reached the station at 1,000 ft from the faces within 5 hr.

- The station at 1,000 ft from the faces location would have needed to be flame resistant and withstand forces in the 2 to 4 psi range.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study given the impossibility of predicting where a random explosion might occur in a case such as this.

9. Blacksville No. 1 Mine Fire – July 22, 1972

1	Locations of victims with respect to working face area (if applicable)	Victims from A-2 Section were found 600 to 800 ft outby their working longwall face; the victims from A-3 Section were found nearly 3,000 ft outby their longwall development face.
2	Location of victims if not associated with a working face	N/A
3	Location of victims with respect to fire or explosion point of origin	The fire was located in the track entry of the 3 North Mains between the A-1 and A-2 Sections. In attempting to escape, the crews from both the A-2 and A-3 sections were advancing in the direction of the fire. The A-2 crew was found about 1,200 ft inby the fire and the A-3 crew was found about 500 ft inby the fire.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	The victims in Section A-2 were found about 400 ft inby where a station at 1,000 ft from the faces would have been located. The report did not indicate if they had used self-rescuers or if they had advanced beyond this point and were forced to retreat by the intensity of the fire. It is likely that if they had used SCSRs and a lifeline, they would have been able to reach a station at 1,000 ft from the faces. The A-3 crew would have easily reached a station at 1,000 ft from the faces. They had advanced about 1,500 ft beyond its location before they perished and, with SCSRs and a lifeline, should have been able to retreat back to it if necessary due to the intensity of the fire.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	A station at 2,000 ft from the faces would have been outby the mouth of the Section in the 3 North Mains very close to the source of the fire and not viable for the A-2 Section crew. A station at 2,000 ft from the faces would have been easily reachable by the A-3 crew (they had already passed its location before they perished).
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	In Section A-2, a station at 1,000 ft from the faces could have saved the victims but a station at 2,000 ft from the faces would not have been viable due to its location outby the mouth of the section and very close to the fire. In Section A-3, a station at 1,000 ft from the faces would not have been subjected to significant forces or flame whereas a station at 2,000 ft from the faces would have been exposed to heat and at least some force from the explosion on July 24.
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	In Section A-3, a station at 2,000 ft from the faces would have been much closer to the point where the miners perished since they had advanced about 2,500 ft from their work area (less distance to backtrack if forced to seek refuge).
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO; no specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	In Section A-2, heat and flame would have impacted a station at 1,000 ft from the faces. In Section A-3, a station at 1,000 ft from the faces would have likely been far enough away to not be impacted.
10	Effect of FLAME on a station at 2,000 ft from the faces	In Section A-2, a station at 2,000 ft from the faces would have been very close to the fire and certainly impacted by heat and flame. In Section A-3, a station at 2,000 ft from the faces would also have likely been impacted by heat and flame.
11	Effect of FLAME on a station per OTHER guidelines	N/A

12	Effect of FORCES on a station at 1,000 ft from the faces	In Section A-2, a station at 1,000 ft from the faces would likely have been exposed to overpressure generated by the explosion inby the fire. No data is provided in the report; however, MSHA's description indicates that the forces were likely only a few psi. In Section A-3, forces would have been even lower on a station at 1,000 ft from the faces.
13	Effect of FORCES on a station at 2,000 ft from the faces	In Section A-3, a station at 2,000 ft from the faces would have likely been exposed to forces similar to those of the station at 1,000 ft from the faces in Section A-2 (see above).
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Rescuers would not have been able to reach the stations from underground due to the intensity of the fire. Stations would have been viable if their locations were pre-surveyed. A flame resistant, explosion proof station with 96 hr of breathable air would give rescuers adequate time to at least drill a hole to the station large enough to supply air, water, and food. This would provide the time required for rescuers to either reach the miners from another direction underground or to drill an escape shaft from the surface.
16	Would additional outby stations have been beneficial?	No; if the miners had been able to escape the immediate area somewhat beyond where the fire was burning, they could have made it safely to clean air.

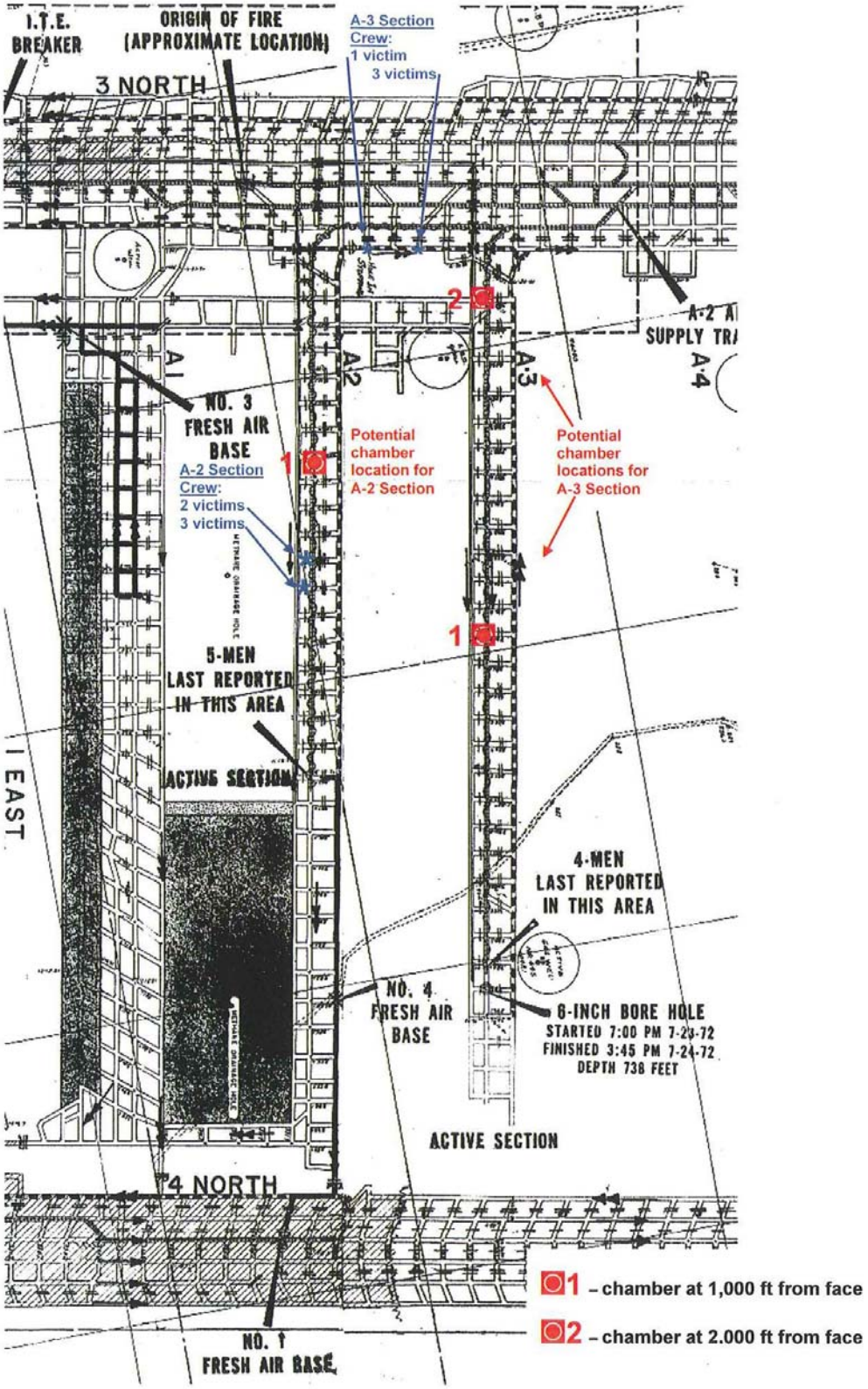

Figure B-9. Blacksville No. 1 mine map

Conclusions from the Blacksville No. 1 Mine Disaster

- A station at 1,000 ft from the faces should have been reachable by all miners affected by the fire using SCSRs and lifelines. For A-2 Section, a station at 1,000 ft from the faces would have been impacted by heat, flame and forces; for A-3 Section, a station would have been impacted by minor explosion forces but likely not by flame or heat.

- A station at 2,000 ft from the faces for the A-3 Section would have been easily reachable by the miners in that section. However, a station at 2,000 ft from the faces for the A-2 section would have been close to the source of the fire and not viable for the miners in that section; also, it would have been subjected to forces from the explosion. For A-3 Section, a station at 2,000 ft from the faces would have been somewhat impacted by heat, flame and forces.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

- This 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 preventing the movement of equipment while miners are located inby will prevent similar disasters in most cases, another suggestion for station positioning might be to avoid locating them within or off track entries when other options are available.

10. Nemacolin Mine Fire – March 26, 1971

1	Locations of victims with respect to working face area (if applicable)	One victim was found right at his face work area next to a roof bolter; the other victim was found about 1,100 ft outby the faces
2	Location of victims if not associated with a working face area	The second victim (who was found 1,100 ft outby) was originally working on installation of a stopping somewhere on the right side of the section (report does not say how far he was from faces or fire)
3	Location of victims with respect to fire or explosion point of origin	The fire was 3 crosscuts (about 300+ ft) outby the faces. The victim near his roof bolter was 4 entries to the left and 3+ crosscuts inby the fire; the second victim was at an undisclosed location on the right hand side of the section installing a stopping (not sure how close to the fire)
4	Would victims have been able to reach a station at 1,000 ft from the faces?	With SCSRs and lifelines, both miners would have likely reached a station at 1,000 ft from the faces but presumably would not have stopped there because they would have reached it while the air was still good and they would have continued to escape the mine.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	-- Ditto for a station at 2,000 ft from the faces --
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	None in this situation (presuming neither of the two victims was sufficiently injured or disoriented to require aborting an escape attempt to take refuge in a station)
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	None in this situation since it is very likely that a station would not have been used in lieu of escaping the mine. Generally speaking, in the case of fires, the further a station is located from the source of the fire the better the chances of it not being affected by flames or thick smoke and the less time it would take for rescuers to arrive there (though this is balanced by the greater risk and time required for miners to reach the station).
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO – No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	Flame would not have impacted a station at 1,000 ft from the faces
10	Effect of FLAME on a station at 2,000 ft from the faces	Flame would not have impacted a station at 2,000 ft from the faces
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	N/A – This was a fire with no forces applicable
13	Effect of FORCES on a station at 2,000 ft from the faces	N/A – This was a fire with no forces applicable
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Difficult to say based on the report. Aside from attempts of some of the miners already on the section to locate their missing comrades, no actual mine rescue efforts under oxygen were made before the fire got out of hand to the point where it was necessary to flood the section. Had stations existed and had the victims made their way to a station, it is likely that rescuers would have been able to reach the station in well under the 5 hr that transpired before the mine was evacuated due to dangerous air conditions.
16	Would additional outby stations have been beneficial?	No; if the miners had been able to escape the immediate area somewhat beyond where a station at 1,000 ft from the faces would have been located, they could have made it safely to clean air.

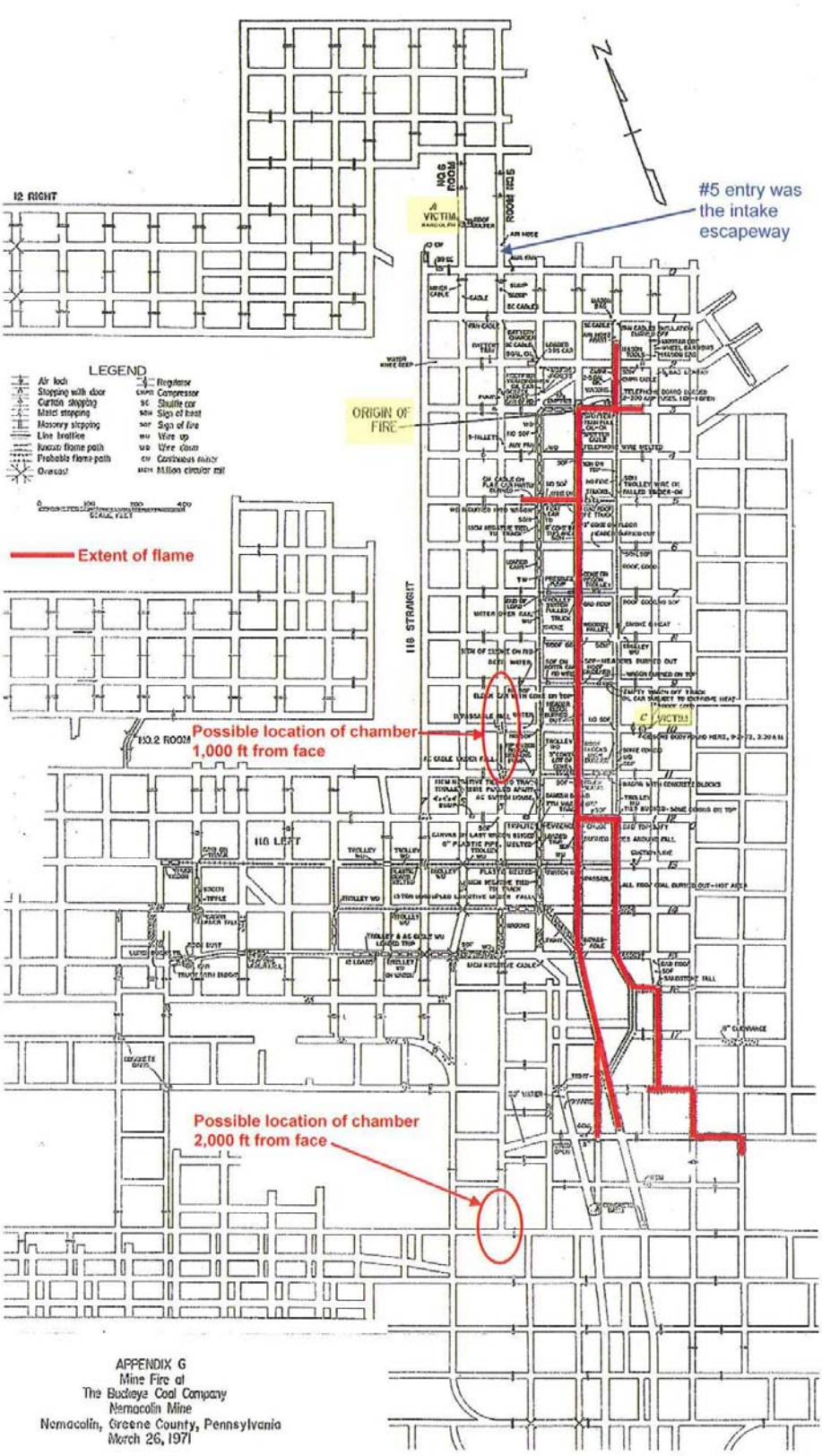

Figure B-10. Nemacolin mine map

Conclusions from the Nemacolin Disaster

- A station either at 1,000 ft or 2,000 ft from the faces would have been easily reachable by both miners using SCSRs and lifelines. However, they would have found good air in the process and likely continued on to escape the mine (same as the other miners who successfully escaped). If they *had* chosen to stay in a station, rescue teams would have likely reached them in well under the 5 hr that transpired before the mine was evacuated due to dangerous air conditions.

- Flames would not have affected a station at either 1,000 ft or 2,000 ft from the faces.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

11. Finley No. 15 and 16 Mine Coal Dust Explosions – December 30, 1970

1	Locations of victims with respect to working face area (if applicable)	No. 15 Mine: 21 miners located at various places in the 2nd Right section No. 16 Mine: 17 miners located at various places in the 1st Left section. Most of the miners in each section were near the faces.
2	Location of victims if not associated with a working face area	Some of the 38 victims were located considerable distances away from their active faces elsewhere in their sections. Location relative to the working areas is not particularly relevant given that 33 miners died instantly from the explosion.
3	Location of victims with respect to fire or explosion point of origin	No. 15 Mine: victims ranged from 600 to 1,500 ft from the point of origin No. 16 Mine: victims ranged from 150 to 400 ft from the point of origin
4	Would victims have been able to reach a station at 1,000 ft from the faces?	The report does not give details on the extent of injuries of the five miners that initially survived the explosion so it is unclear if they could have reached a station if SCSRs had been available. Also, the seam height was less than 36 in. so travel speed would have been severely impacted. Note that a single station would have serviced both mines active faces.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	A station at 2,000 ft from the faces would likely not have been provided because it would have been located within about 400 ft of the mine portals.
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	N/A
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	N/A
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	NO; no specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study
9	Effect of FLAME on a station at 1,000 ft from the faces	A station at 1,000 ft from the faces would have been within 1000 ft of where the explosion occurred and within the area showing destroyed stoppings and flame spread. This would indicate that a station in this location would have needed to be explosion proof and flame resistant.
10	Effect of FLAME on a station at 2,000 ft from the faces	N/A
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	A station at 1,000 ft from the faces would have needed to be explosion proof (see Item No. 9 above).
13	Effect of FORCES on a station at 2,000 ft from the faces	N/A
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	Rescue teams from the Bureau of Mines and State entered No. 15 Mine at 3:00 pm and No. 16 Mine at 4:00 pm on 12/30. The first bodies were reached by 7:00 pm on 12/30, about 6.5 hr after the explosion. All rescuers and bodies were out of the mine by 10:00 am on 12/31, about 21.5 hr after the explosion.
16	Would additional outby stations have been beneficial?	N/A – the mine portals were only about 2,400 ft away from the working faces.

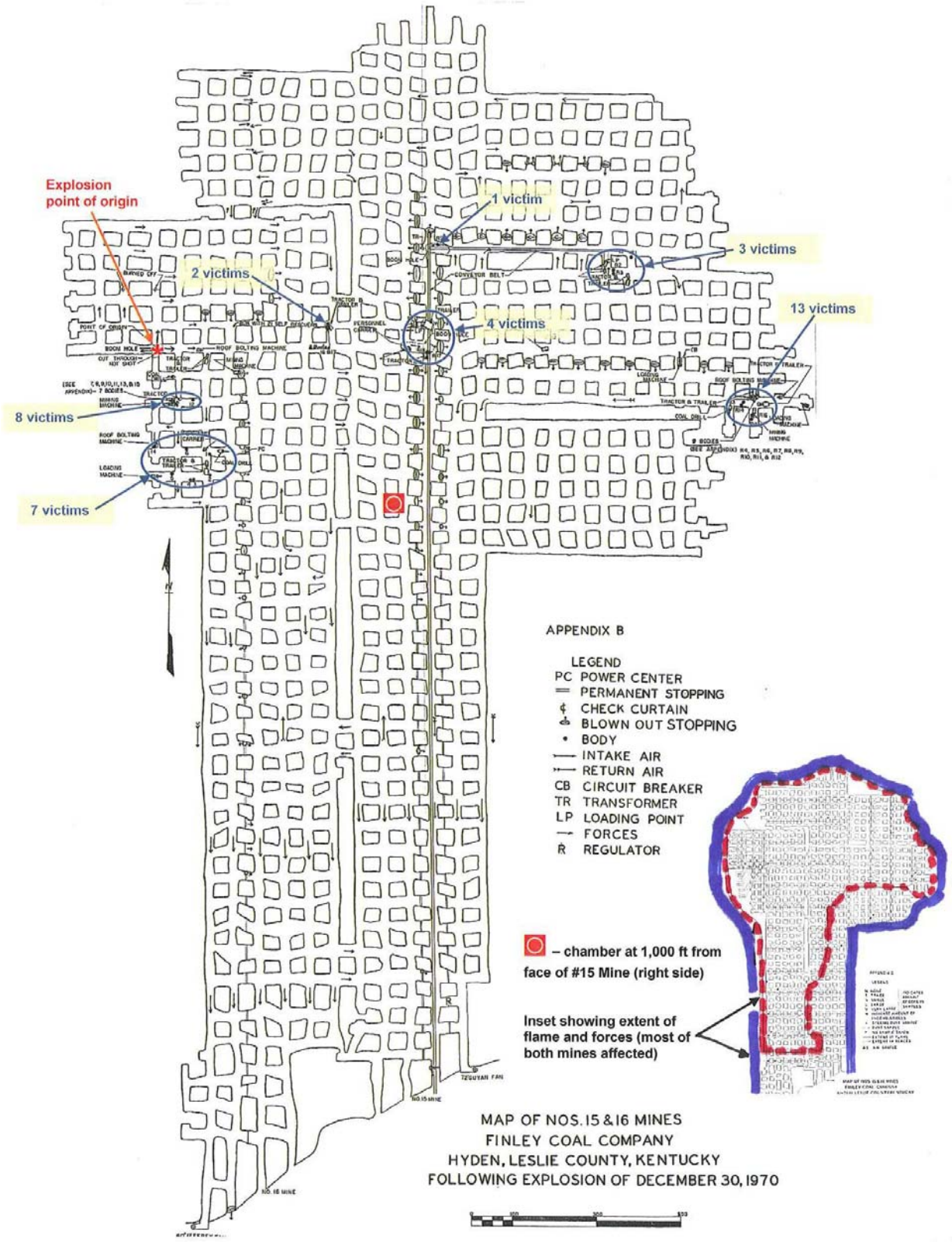

Figure B-11. Finley mines No. 15 and 16 mine map

Conclusions from the Finley Disaster

- The explosion did not occur right at a coal producing working face but rather nearby at a site being prepared for a new belt tailpiece. This was just off to the side of the 1st Left section of No. 16 Mine but was about 1,500 ft from the 2nd Right section of No. 15 Mine.

- The report does not give details on the extent of injuries of the 5 miners that initially survived the explosion so it is unclear if they could have reached a station at 1,000 ft from the faces if SCSRs had been available. If so, the station would have needed to be explosion proof and flame resistant. Rescuers would have reached them within about 6.5 hr after the explosion.

- A station at 2,000 ft from the faces would likely not have been provided because it would have been located within about 400 ft of the mine portals.

- No specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

12. Pyro No. 2 Mine Explosion – November 30, 1970

1	Locations of victims with respect to working face area (if applicable)	N/A – See below
2	Location of victims if not associated with a working face area	The two men affected by the explosion (a surveyor and his assistant) were traveling in a recently mined out section of the mine to take measurements of the area; the active working areas were some distance away (not defined in the report and not relevant to the explosion)
3	Location of victims with respect to fire or explosion point of origin	The two men (only one a victim) were right at the point of origin because one of the men ignited gas by attempting to light a cigarette.
4	Would victims have been able to reach a station at 1,000 ft from the faces?	The lone victim would have been able to reach fresh air and evacuate the mine if he'd had an SCSR to don; he would not have used a station. It is likely that if a station had existed in the area before it had been mined out, it would have been relocated and so not available to the victim.
5	Would victims have been able to reach a station at 2,000 ft from the faces?	-- See above --
6	Factors in favor of a station at 1,000 ft versus 2,000 ft from the faces	N/A – Since the explosion occurred well away from active working areas
7	Factors in favor of a station at 2,000 ft versus 1,000 ft from the faces	N/A – Since the explosion occurred well away from active working areas
8	Would a station at a location other than 1,000 ft or 2,000 ft from the faces have been better?	N/A – Since the explosion occurred well away from active working areas
9	Effect of FLAME on a station at 1,000 ft from the faces	N/A – Even if a station had remained within 1000 ft of the mined out area, the explosion was confined to a very localized region within the area
10	Effect of FLAME on a station at 2,000 ft from the faces	N/A – Even if a station had remained within 2000 ft of the mined out area, the explosion was confined to a very localized region within the area
11	Effect of FLAME on a station per OTHER guidelines	N/A
12	Effect of FORCES on a station at 1,000 ft from the faces	N/A – Even if a station had remained within 1000 ft of the mined out area, the explosion was confined to a very localized region within the area
13	Effect of FORCES on a station at 2,000 ft from the faces	N/A – Even if a station had remained within 2000 ft of the mined out area, the explosion was confined to a very localized region within the area
14	Effect of FORCES on a station per OTHER guidelines	N/A
15	Time that rescuers would have made contact with trapped miners	N/A – Since stations would not have been relevant to this situation (rescuers arrived to retrieve the victim in little over an hour after the explosion)
16	Would additional outby stations have been beneficial?	No – If the sole victim had been able to escape the immediate area, he could have made it safely to clean air.

Figure B-12. Pyro No. 2 mine map

Conclusions from the Pyro No. 2 Disaster

- The explosion did not occur at a coal producing working face. It occurred in a mined out area being measured by a surveyor and his assistant, but it did occur in their immediate vicinity because gas was ignited by lighting a cigarette.
- Stations at either 1,000 ft or 2,000 ft from the faces would not have been applicable in this case. The lone victim would have been able to reach fresh air and evacuate the mine if he'd had an SCSR to don; he would not have used a station. It is likely that if a station had existed in the area before it had been mined out, it would have been relocated and so not available to the victim.
- Based on the above, no specific rationale for a station location different from either 1,000 ft from the faces or 2,000 ft from the faces surfaced in this study and outby stations would not have been relevant.

Appendix C. Bibliography of Mine Disasters Study

The following reports, all provided by the MSHA Library in Beckley, WEST VIRGINIA, were used in the review of past mining disasters:

No.	Date of Disaster	Mine	Report Title
1	April 02, 1970	Compass No. 2 Mine	Report of Coal-Mine Explosion, Compass No. 2 Mine, Clinchfield Coal Company (Division of the Pittston Company), Dola, Harrison County, WV, April 2, 1970
2	April 10, 1970	Homer City Mine, Helen Mining Co.	Report of Coal Mine Explosion, Homer City Mine, The Helen Mining Company, Homer City, Indiana County, Pennsylvania, April 10, 1970
3	Novembr 30, 1970	Pyro No. 2 Mine	Report of Fatal Coal-Mile Gas Ignition, Pyro Mine No. 2, Pyro Mining Company, Sullivan, Union County, Kentucky, November 30, 1070
4	December 30, 1970	Finley Nos. 15 and 16 Mines	Official Report of Major Mine Explosion Disaster, Nos. 15 and 16 Mines, Finley Coal Company, Hyden, Leslie County, Kentucky, December 30, 1970
5	March 26, 1971	Nemacolin Mine	Report of Coal Mine Fire, Nemacolin Mine, The Buckeye Coal Company, Nemacolin, Greene County, Pennsylvania, March 26, 1971
6a	July 22, 1972	Blacksville No. 1 Mine	Preliminary Report of Major Coal Mine Fire Disaster and Sealing Operations, Blacksville No. 1 Mine, Consolidation Coal Company, Blacksville Division, Blacksville, Monongalia County, WV, July 22, 1972
6b	July 22, 1972	Blacksville No. 1 Mine	Final Report of Major Coal Mine Fire Disaster and Recovery Operations, Blacksville No. 1 Mine, Consolidation Coal Company, Blacksville Operations, July 22, 1972
7	December 16, 1972	Itmann No. 3 Mine	Official Report of Major Mine Explosion Disaster, Itmann No. 3 Mine (ID. 46-01576), Itmann Coal Company, Itmann, Wyoming County, WV, December 16, 1972
8	Sep 25, 1973	No. 4 Mine, Oakwood Red Ash Coal	Official Report Coal Mine Explosion, No. 4 Mine, Oakwood Red Ash Coal Corporation, Vansant, Buchanan County, Virginia, September 25, 1973
9	March 09 and March 11, 1976	Scotia Mine	Report of Investigation, Underground Coal Mine Explosions, Scotia Mine – ID 15-02055; Scotia Coal Company, Ovenfork, Letcher County, Kentucky, March 9 and 11, 1976
10	March 01, 1977	Porter Tunnel Mine, Kocher Coal	Report of Investigation, Underground Coal Mine Inundation (Water), Porter Tunnel Mine – ID 36-01892, Kocher Coal Company, Tower City, Schuylkill County, Pennsylvania, March 1, 1977
11	April 04, 1978	Moss No. 3 Portal A Mine	Report of Investigation, Underground Coal Mine Inundation (Blackdamp), Moss No. 3 Portal A Mine (I.D. 44-01642), Clinchfield Coal Company, Duty, Dickenson County, Virginia, April 4, 1978
12	Novembr 07, 1980	Ferrell No. 17 Mine	Interim Report of Investigation, Underground Coal Mine Explosion, Ferrell No. 17 Mine – ID No. 46-02493, Westmoreland Coal Company, Uneeda, Boone County, WV, November 7, 1980
13	April 15, 1981	Dutch Creek No. 1 Mine	Report of Investigation, Underground Coal Mine Explosion, Dutch Creek No. 1 Mine – I.D. No. 05-00301, Mid-Continent Resources, Inc., Redstone, Pitkin County, Colorado, April 15, 1981

No.	Date of Disaster	Mine	Report Title
14	December 07, 1981	No. 11 Mine, Adkins Coal	Report of Investigation, Underground Mine Coal Dust Explosion, No. 11 Mine (ID No. 15-02290), Adkins Coal Company, Kite, Knott County, Kentucky, December 7, 1981
15	December 08, 1981	No. 21 Mine, Grundy Mining	Report of Investigation, Underground Coal Mine Explosion, No. 21 Mine – I.D. No. 40-00524, Grundy Mining Company, Incorporated, Whitwell, Marion County, Tennessee, December 8, 1981
16	January 20, 1982	RFH No. 1 Mine	Report of Investigation, Underground Coal Mine Dust Explosion, No. 1 Mine (ID No. 15-12624), RFH Coal Company, Craynor, Floyd County, Kentucky, January 20. 1982
17	June 21, 1983	McClure No. 1 Mine	Report of Investigation, Underground Coal Mine Explosion, McClure No. 1 Mine – I.D. No. 44-04251, Clinchfield Coal Company, McClure, Dickenson County, Virginia, June 21, 1983
18	July 03, 1983	Homer City Mine	[Cover page missing]; report pertains to a methane and coal dust explosion at the Homer City Mine, The Helen Mining Company, Homer City, Indiana County, Pennsylvania on July 3, 1983.
19	December 19, 1984	Wilberg Mine	Report of Investigation, Underground Coal Mine Fire, Wilberg Mine, I.D. No. 42-00080, Emery Mining Corporation, Orangeville, Emery County, Utah, December 19, 1984
20	December 11, 1985	No. 2 Slope Mine, M.S.W. Coal Co.	Report of Investigation (Underground Coal Mine), Underground Coal Mine Explosion, No. 2 Slope Mine (ID 36-06279), M.S.W. Coal Company, Carlstown, Schuylkill County, Pennsylvania, December 11, 1985
21	February 06, 1986	Loveridge No. 22 Mine	Report of Investigation (Surface Area of Underground Mine), Multiple Fatal Suffocation Accident, Loveridge No. 22 (ID No. 46 01433, Consolidation Coal Company, Fairview, Marion County, WV, February 6, 1986
22	August 09, 1986	Pyro No. 9 Slope	Report of Investigation (Underground Coal Mine), Fatal Mine Explosion, Pyro No. 9 Slope, Wm. Station (I.D. No. 15-13881), Pyro Mining Company, Sturgis, Union County, Kentucky, August 9, 1986
23	January 08, 1987	Dutch Creek No. 2 Mine	Report of Investigation (Underground Coal Mine), Fatal Methane/Air Ignition Accident Investigation, Dutch Creek No. 2 Mine (ID No. 05-00469), Mid-Continent Resources, Inc., Redstone, Pitkin County, Colorado, January 8, 1987 (Injury), January 28, 1987 (Death)
24	December 26, 1987	No. 1 Mine, Double R Coal	Report of Investigation (Underground Coal Mine), Underground Coal Mine Explosion, No. 1 Mine (ID No. 44-05186), Double R Coal Company, Inc., Duty, Dickenson County, Virginia, December 26, 1987
25	September 13, 1989	Pyro No. 9 Slope	Report of Investigation, Underground Coal Mine Explosion, Pyro No. 9 Slope, William Station Mine – I.D. No. 15-13881, Pyro Mining Company, Sullivan, Union County, Kentucky, September 13, 1989
26	January 16, 1991	No. 1 Mine, Fire Creek Inc.	Accident Investigation Report (Underground Coal Mine), Explosion, No. 1 Mine (ID No. 46-07512), Fire Creek, Inc., Superior, McDowell County, WV, January 16, 1991
27	March 19, 1992	Blacksville No. 1 Mine	Report of Investigation, Underground Coal Mine Explosion, Blacksville No. 1 Mine – I.D. No. 46-01867, Consolidation Coal Company, Blacksville, Monongalia County, WV, March 10, 1992

No.	Date of Disaster	Mine	Report Title
28	December 07, 1992	No. 3 Mine, Southmountain Coal Co.	Report of Investigation, December 7, 1992, Underground Coal Mine Explosion, No. 3 Mine – ID. No. 44-06594, Southmountain Coal Co., Inc., Norton, Wise County, Virginia
29	Novembr 30, 1993	Elmo No. 5 Mine	Report of Investigation, November 30, 1993, Underground Coal Mine Explosion, Elmo No. 5 Mine – I.D. No. 15-16856, A.A.&W. Coals, Inc., Feds Creek, Pike County, Kentucky
30	March 10, 1996	No. 4 Mine, Jim Walter Resources	Report of Investigation, Other Fatal (Asphyxiation), March 10, 1996, No. 4 Mine, Jim Walters Resources, Incorporated, Brookwood, Tuscaloosa County, Alabama, I.D. No. 01-01247
31	July 31 to August 01, 2000	Willow Creek Mine	Report of Investigation, Underground Coal Mine Explosions, July 31 – August 1, 2000, Willow Creek Mine – MSHA ID. No. 42-02113, Plateau Mining Corporation, Helper, Carbon County, Utah
32	Sep 23, 2001	No. 5 Mine, Jim Walter Resources	Report of Investigation, Fatal Underground Coal Mine Explosions, September 23, 2001, No. 5 Mine, Jim Walter Resources, Inc. Brookwood, Tuscaloosa County, Alabama, ID No. 01-01322
33	July 24, 2002	Quecreek No. 1 Mine	Report of Investigation, Underground Coal Mine Nonfatal Entrapment, July 24, 2002, Quecreek No. 1 Mine, ID No. 36-08746, Black Wolf Coal Company, Inc., Quecreek, Somerset County, Pennsylvania
34	January 02, 2006	Sago Mine	Report of Investigation, Fatal Underground Coal Mine Explosion, January 2, 2006, Sago Mine, Wolf Run Mining Company, Tallmansville, Upshur County, WV, ID No. 46-08791
35	January 19, 2006	Aracoma Alma Mine No. 1	Report of Investigation, Fatal Underground Coal Mine Fire, January 19, 2006, Aracoma Alma Mine No. 1, Aracoma Coal Company, Inc., Stollings, Logan County, WV, I.D. No. 46-08801
36	May 20, 2006	Darby Mine No. 1	Report of Investigation, Fatal Underground Coal Mine Explosion, May 20. 2006, Darby Mine No. 1, Kentucky Darby LLC, Holmes Mill, Harlan County, Kentucky, ID No. 15-18185
37	October 23, 2006	R&D Coal Co., Inc. Mine	Report of Investigation, Underground Coal Mine Fatal Methane Explosion, October 23, 2006, R&D Coal Company, Inc. Mine, R&D Coal Company, Inc., Lincoln, Schuylkill County, PA. ID No. 36-02053

38	Various	Various	Historical Summary of Mine Disasters in the United States, Volume II – Coal Mines – 1959-1998, U.S. Department of Labor, Elaine L. Chao, Secretary, 1998, Reprinted 2001; sections reviewed as part of the analysis in this project were:
			- Section 1, Historical Summary of Coal Mine Explosions in the United States, 1959-81, Scotia Mine, p. 13
			- Section 4, Summaries of Coal Mine Disasters Between 1958 and 1998:
			  - Nemacolin Mine, p. 60
			  - Scotia Mine, p. 88
			  - No. 2 Mine, P and P Coal Company, p. 97
			  - No. 5 Mine, Grays Knob Coal Company, p. 111
			  - Greenwich Collieries No. 1 Mine, p. 122
			  - No. 3 Mine, R and R Coal Company, p. 123
			  - No. 3 Mine, Granny Rose Coal Company, p. 131

The disaster reports listed above, not available for download from MSHA's website (at http://www.msha.gov/TRAINING/LIBRARY/library.HTM), were obtained as hard copy from:

Melody E. Bragg, Technical Information Specialist
Technical Information Center and Library
National Mine Health and Safety Academy
1301 Airport Road
Beaver, WV 25813-9426

During the course of this project, we also visited the following contacts at the MSHA District 9 headquarters in Denver Colorado as well as two western coal mines to discuss strategies for employing refuge chambers in underground mines:

William G. "Bill" Denning, Staff Assistant – Civil Engineer, P.E.
Coal Mine Safety & Health, District 9
Denver Federal Center, 2nd St., Bldg. 25
Denver, Colorado 80225

Hillary A. Smith, Mining Engineer
Coal Mine Safety & Health, District 9
Denver Federal Center, 2nd St., Bldg. 25
Denver, Colorado 80225

David Hales, Health & Safety Superintendent
bhpbilliton - New Mexico Coal
San Juan Coal Co.
P.O. Box 561
Waterflow, NM 87421

Richard "Dick" Conkle, Manager - Safety
Peabody Energy – Twentymile Coal Company
29515 Routt County Road No. 27
Oak Creek, Colorado 80467

Appendix D - Overview of Current Portable Refuge Chambers and Refuge Station Atmosphere Systems

Table D-1 shows a summary chart of commercial portable refuge chambers and refuge station atmosphere systems, currently offered as of the date of this report. Two systems, LifePod and Mine Lifeline, do not provide chambers. LifePod is a breathing mask and manifold system without a surrounding enclosure for the miners. Mine Lifeline's Outby Refuge System is a complete breathable air system for a bulkhead-based refuge station in a crosscut or blind entry, including a purgeable airknife entry system.

Table D-1. Summary chart for the commercial chambers/refuge station atmosphere system

Manufacturer	Product Name	Shelter Type	Oxygen Source	Carbon Dioxide Scrubbing Method	Carbon Monoxide Protection Method	Powered or Passive Subsystem	WV Approval Status	Shelter Size Range	Shelter Weight Range	Shelter ROM Price Range (Can Vary Widely with Options)	Comments
ChemBio Shelter Inc.	Life Shelter	Rigid/Inflatable 10 to 50 man	O_2 Cylinders	Soda lime curtains (Lithium curtains can be substituted) Shelter is pressurized, and this air movement feeds the scrubber curtains	Precious metal catalyst converted to CO_2, and scrubbed	Passive	Y	Stowed box: 12 ft x 7 ft x 25 in. Deployed: up to 16 ft W x 30 ft L x various heights	10,000 to 14,000 lb	Pricing not provided	Only company doing CO removal with chemical catalyst scrubber
Dräger Safety Inc.	Dräger Emergency Shelter	Rigid 10 to 16 man	O_2 Cylinders	Soda Lime, powered air flow	Constant air purge through overpressure valves. Airlock can be specially purged.	Compressed air powered CO_2 scrubber	Y	16 man: 8 ft W x 20 ft L(adjustable) x 48 in. H 10 man: 8 ft W x 20 ft L (adjustable) x 36 in. H	~10,000 for 16 man shelter, plus 2 air skids additional weight 14,000 total	TBD (~75 to 150K range likely)	First 16 man unit being built now, ready February 2008. Special high-moisture content soda lime used. Dräger are a large company, and have a wide variety of similar survival chambers built, -prior testing may be valid and available.
Kennedy Metal Products Inc.	Kennedy Chamber	Rigid 10 to 33 man	O_2 cylinders (plus secondary O_2 mask system)	Lithium Hydroxide curtains	Breathable air purge capability, 3 x chamber volume. Also auxiliary O_2 manifold and face masks should some people enter or leave. Constant overpressure	Passive	Y	(7 ft to 12 ft) w x (20 ft to 40 ft) L x (24 in. to 84 in.) H	5 ft H chamber weighs ~24,000 lb	~80 to 90K for 16 man unit (450 models available)	Extensive physical testing including blast survival and flash fire tests in a custom built test building. Proprietary CO purge method - not dilution.
Strata Products (USA) Inc.	1) Fresh Air Bay	Rigid/Inflatable 10, 16, or 35 man	O_2 cylinders	Soda lime, powered air flow. (Lithium curtains offered as alternative option)	Breathable air purge capacity, dilution method. Extra large airlock area to let more men in at once. Constant overpressure	Compressed air powered CO_2 scrubber	Y	Stowed boxes: up to ~6.5 ft x 4 ft x 16 ft Deployed tent: up to ~12 ft x 37 ft x various heights	~14,000 to 16,000 lb	Pricing not provided	Design based on proven Australian design, test data may be available
	2) Coal Mine Refuge Chamber	Rigid 8, 16, 20, 24, 36 man	O_2 cylinders	Soda lime, powered air flow. (Lithium curtains offered as alternative option)	Breathable air purge capacity, dilution method. Airlock PVC curtain rather than sealed area, purge after entry	Compressed air powered CO_2 scrubber	Y	7 ft w x (12 ft -22 ft L) x (42 in. -84 in. H)	~20,000 lb	Pricing not provided	Design based on proven Australian design, test data may be available
Modern Mine Safety Supply LLC	Emergency Refuge Shelter	Rigid 16, 26 man	O_2 cylinders, medical grade	RANA "Refuge One" Air Center enclosed system, Soda lime cartridges to fill main tank.	Breathable (airlock only) purge capability for initial purge (5 min). Positive pressure system	24V DC Dry cell battery powered air blower, operates at 80 to 100 cubic ft (MSHA approved)	Y	25.5 ft x 8.5 x (48 in. +)	~19,000 for 26 man (empty)	~60 to 100K Depending on no. of miners and options	RANA atmosphere system has been separately man tested for 24 hr. Battery operated blower system has been MSHA approved
LifePod	LifePod	Exposed, Mask/ Manifold 16 man (more possible)	Breathable air cylinders	None, exhausted to mine ambient through exhale valve	None necessary, sealed masks prevent incursion. (Masks are NIOSH approved SCBA 13, can be disengaged from manifold to switch to a 1 hr supply for walking out)	None	Pending	~16 ft x 8.5 ft x 28 in.	~14,000	~75 to 100K Depending on no. of miners and options	Only company with no physical shelter, miners sit in the open with masks on
Mine Lifeline	Outby Refuge System	Atmosphere management system, provided for an outby bulkhead refuge station	O_2 Cylinders	Lithium Hydroxide curtains	Double door airknife manway system is purgeable for CO protection	Passive	Does not meet WV criteria for "man-made walls"	No limit on refuge size. Main supply box: 8 ft x 12 ft x 42 in. H	Main system box weight: (Less than 4500 lb) Airknife egress system: 400 lb	~35 to 40K	The Mine Lifeline outby refuge system is portable, designed to be deployed in a crosscut or stub with a bulkhead wall, egress is provided through an airknife door placed integral with the bulkhead wall. System has been man tested for 96 hr

Portable Refuge Chamber and Refuge Station Atmosphere System Specifications

The coal mine ready refuge chamber systems and refuge station atmosphere systems were investigated in some detail by Foster-Miller through communications with the vendors, and although not exhaustively complete, a basic chart with specifications on each is presented below. (See Tables D-2 through D-8 and Figures D-1 through D-8) These charts are shown side by side for easy comparison with the guidelines from this report, the MSHA proposed rule, and rules from WV and MSHA. It is worth noting that the vendors have expressed that they are continually updating and refining their chambers to meet all the new regulations, and it is possible some specifications may be changed since Foster-Miller's last communications with them.

Table D-2. ChemBio Shelter Inc., Life Shelter

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	ChemBio "Life Shelter" Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	96 hr
Initial Event Survival Standards		15 psi overpressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2 sec; flash fire of 300°F for 3 sec	Peak overpressure 15 psi flash fire of 300°F for 3 sec (per NFPA-2113)	N/A	In stowed configuration, the container is shown by FEA analysis to withstand 15 psi peak overpressure for a single event
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/handling	Protect for normal handling and mine conditions	N/A	Steel container sized to be moveable by mine scoop, has tow hook attachments, and is skid mounted. Activation switch is protected behind an armored panel
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O_2 above 19.5%	N/A	Oxygen is added from cylinders, adjusted as necessary to be within limits
	Carbon Dioxide Level	CO_2 max. 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	CO_2 is removed by passive scrubbing of soda lime curtains. Air circulates naturally via moving air that pressurizes chamber
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	CO is actively converted to CO_2 via a catalyst reaction, and CO_2 scrubbed out as with the rest
	Apparent Temperature	Maximum 95°F	Maximum 95°F	Maximum 95°F	Maximum 95°F	Will meet specifications
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous*	Not specified	N/A	0.8	Assumption not specified

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	ChemBio "Life Shelter" Specifications
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/min) at rest 4.2 CFH (1.982 L/min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L / Min/Man)	N/A	1.32 CFH/Man (0.62297 L /min/man)	Assumption not specified
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest1/5 at moderate activity	Assumption not specified
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/Man (0.5097 L/ Min/Man)	Assumption not specified
	CO_2 Scrubbing Provisions	0.019 CFM/occupant (0.538 L/ min/occupant)*.	1.08 CFH/Man (0.5097 L /min/man)	N/A	LiOH curtains (0.244 lb/Man/hr) or Soda Lime equivalent	Soda Lime Curtains, passive hanging
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	ChemBio may be a special case, CO is actively controlled
	Design air flow to chamber	1.9 to 3.5 cfm/ occupant (53.8 to 107.6 L/ min/occupant)	Not specified	N/A	N/A	Not specified
	Chamber overpressure required (if the only system of gas incursion protection)	5 in of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	Not specified
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH_4	(Additional information needed)
Egress Provision To Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	Airlock provided
Powered Subsystem, Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	No powered subsystems
Water Provision		9 quart/occupant	Minimum 2.25 quart/ person/day	Minimum 8 quart of water/Miner	N/A	Will meet specifications
Food Provision		6960 calories of Food/occupant	Minimum 2000 calories of food/person/ day	Minimum 4000 calories of food/Miner	N/A	Will meet specifications
Human Waste Disposal		Minimum 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	Chemical toilet provided, bags are placed into a disposal chute which goes into an airtight pouch, stays in shelter.

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	ChemBio "Life Shelter" Specifications
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	Will meet specifications
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	(Additional information needed)
Inside Repairs By Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min	Contain manufacturer recommended repair materials	N/A	(Additional information needed)
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	Is it necessary? If shelter is up , it's occupied
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communication s to the surface and mine's communication system	N/A	(Additional information needed)
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	Will meet specifications
Cooling Methods		Not specified	Not specified	N/A	N/A	No active temperature control, but chemical neck cooling collars are supplied. Endothermic reaction activated by neck heat to produce net cooling of individuals.
Humidity Control		Not specified	Not specified	N/A	N/A	Humidity is controlled by a desiccant, which maintains RH 75 to 80%
Seam Height Capability		Not specified	Not specified	N/A	N/A	32 in. to 40 in. height
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	*3 step deployment:* Pull release, open valve 1 for breathable air to shelter, open valve 2 for raising shelter to full height by inflating airbeams. *Once in shelter, 3 steps to operate:* Set O_2 rate, hang soda lime curtains (change as necessary), switch on gas analyzer

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	ChemBio "Life Shelter" Specifications
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	Not specified
Physical Testing Performed /Planned		Not specified	May be required for application.	N/A	N/A	*Performed:* Permeability of fabric, puncture resistance of fabric, O_2/CO_2 levels. *Planned:* Fabric flame retardancy
No. of Occupants		N/A	N/A	N/A	N/A	10 to 30 man
Size and Weight		Not specified	Not specified	N/A	N/A	Size: 12 ft W x (20 ft to 30) L x (32 in. or 40 in.) H, weight: 10,000 to 14,000 lb
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel	N/A	N/A	(Additional information needed)
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

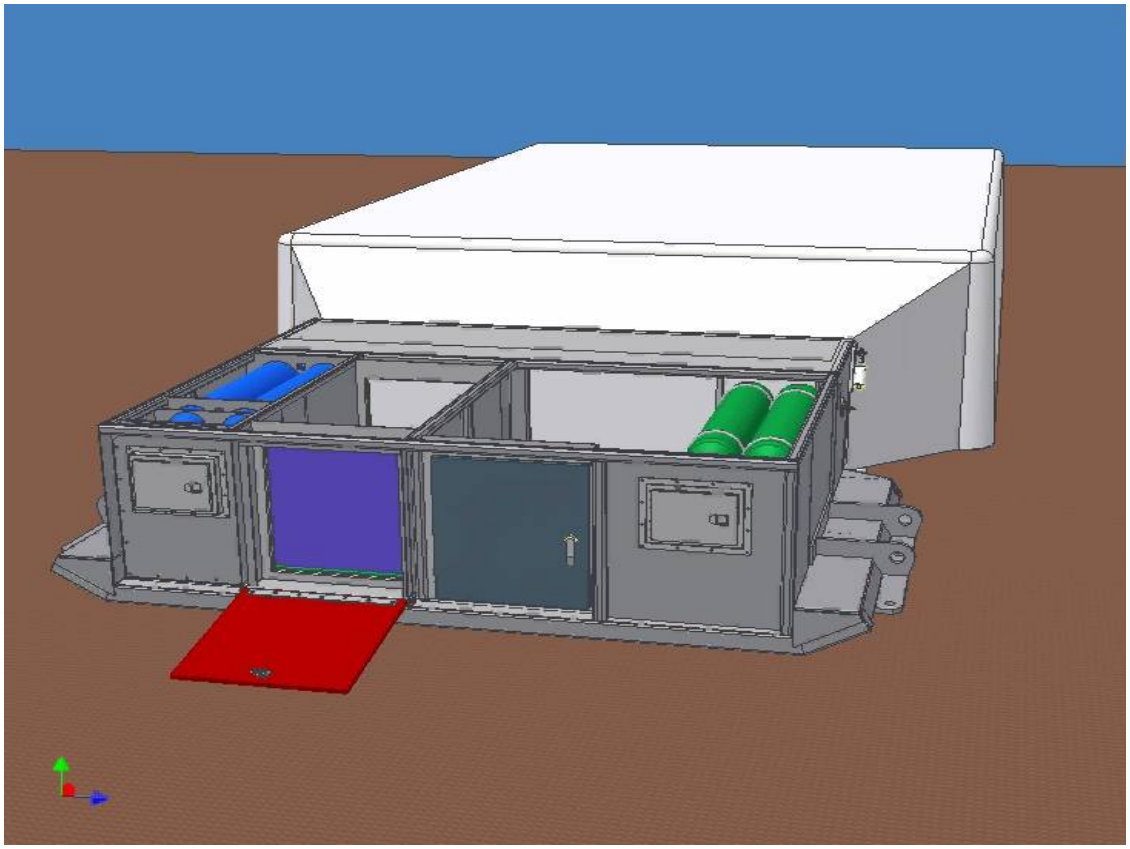

Figure D-1. ChemBio Shelter Inc., Life Shelter

Table D-3. Draeger Safety Inc., Draeger Emergency Shelter

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules For Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Dräger Emergency Shelter Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	96 hr
Initial Event Survival Standards		15 psi overpressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2; flash fire of 300°F for 3 sec	Peak overpressure 15 psi flash fire of 300°F for 3 sec (per NFPA-2113)	N/A	FEA analysis shows shelter will survive a 15 psi peak over-pressure, and 300°F flash fire
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/handling	Protect for normal handling and mine conditions	N/A	Skid mounted, tow hooks provided, steel construction
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O2 above 19.5%	N/A	Adjusted as necessary to suit conditions monitored by gas analyzer. O_2 provided via cylinders.

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules For Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Dräger Emergency Shelter Specifications
	Carbon Dioxide Level	CO_2 maximum 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	CO_2 level designed to meet spec via soda lime cartridge scrubber powered by chamber airflow. Change cartridge when meter indicates high level. Drive air injector system, no dedicated cylinders.
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	Airlock can be purged multiple times. Chamber is over-pressured by the general airflow, and valved to give constant leakage protecting against CO and exterior gases
	Apparent Temperature	Maximum 95°F	Maximum 95°F	Maximum 95°F	Maximum 95°F	Analysis has shown no active cooling needed (for the WV mine temperatures 50 to 58°F) to maintain temp. spec.
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous*	Not specified	N/A	0.8	1.0 assumed for calculations
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/ min) at rest 4.2 CFH (1.982 L/ min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L /min/man)	N/A	1.32 CFH/Man (0.62297 L /min/man)	0.4 L/man/min
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest 1/5 at moderate activity	Not specified
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/Man (0.5097 L/ min/man)	0.4 L/man/min

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules For Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Dräger Emergency Shelter Specifications
	CO_2 Scrubbing Provisions	0.019 CFM/occupant (0.538 L/min /occupant)*.	1.08 CFH/Man (0.5097/min/man)	N/A	LiOH curtains: 0.244 lb/Man/hr (or equivalent in soda lime etc.)	*For 16 man shelter/96 hr:* 45 soda lime cartridges provided, with 720 L CO_2 processing capacity per cartridge (until 0.3% CO_2). Using Dragersorb S soda lime (high 21% water content)
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	Constantly being purged by controlled valve leakage, but airlock can be specially purged multiple times
	Design air flow to chamber	1.9 to 3.5 cfm/ occupant (53.8 to 107.6 L/ min/occupant)	Not specified	N/A	N/A	Not specified (Additional information needed)
	Chamber overpressure required (if the only system of gas incursion protection)	5 in of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	At least 1 m Bar (100 Pa), exhaust valves and an overpressure gauge
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH4	Gas analyzer monitors O_2, CO_2, CO and one other custom specified gas e.g., CH_4. Using "Miniwarn" analyzer.
Egress Provision to Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	Airlock at entry, can be purged multiple times, also rear escape hatch provided
Powered Subsystem, Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	CO_2 scrubber is powered by the general supplied airflow into the chamber, an air injected venturi system
Water Provision		9 quart/occupant	Minimum 2.25 quart/person/ day	Minimum 8 quart of water/Miner	N/A	Will meet specifications
Food Provision		6960 calories of Food/occupant	Minimum 2000 calories of food/person/day	Minimum 4000 calories of food/Miner	N/A	Will meet specifications

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules For Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Dräger Emergency Shelter Specifications
Human Waste Disposal		Min 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	Liquid and solid waste locks are provided to move toilet waste outside the shelter (located in the main airlock.)
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	Will meet specifications
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	Thorough inspection and maintenance manual will be provided, including test methods, and checklists. Tamper-proof seals provided.
Inside Repairs By Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min	Contain manufacturer recommended repair materials	N/A	Basic toolkit provided, plus repair suite including plugs, rubber sheets, silicone sealant.
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	Will meet specifications
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communications to the surface and mine's communication system	N/A	No system included, but provision made for future system via gas tight penetrations
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	Will meet specifications
Cooling Methods		Not specified	Not specified	N/A	N/A	No active cooling, analysis shows not necessary, good factor of safety with radiation from shelter in 58°F ambient mines

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules For Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Dräger Emergency Shelter Specifications
Humidity Control		Not specified	Not specified	N/A	N/A	Not actively removed, but managed via floor channels and super absorbents for condensate. Occupants are isolated from floor moisture. Some drying occurs via airflow
Seam Height Capability		Not specified	Not specified	N/A	N/A	36 in. to 48 in. Height
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	*4 Steps to operate:* turn breathable air on to set point, turn O_2 on to set point, load soda lime cartridges into scrubber, switch on gas analyzer
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	Not specified
Physical Testing Performed/ Planned		Not specified	May be required for application.	N/A	N/A	Analysis only, to date (Shelter not built at time of writing)
No. of Occupants		N/A	N/A	N/A	N/A	10 to 16 man
Size and Weight		Not specified	Not specified	N/A	N/A	*10 man type:* 8 ft W x 20 ft L (adjustable) x 36 in. H, weight 8900 lb *16 man type:* 8 ft W x 20 ft L (adjustable) x 48 in. H, weight 9900 lb *Separate skid* for breathable air cylinders: 8 ft W x 15 ft L x 36 in. or 48 in. H, weight max. approximately 13000 lb
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates.	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel.	N/A	N/A	Full, thorough manual provided, with all maintenance and training required, test procedures and checks. Approximately 4 year shelf life quoted on the Dragersorb S soda lime
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

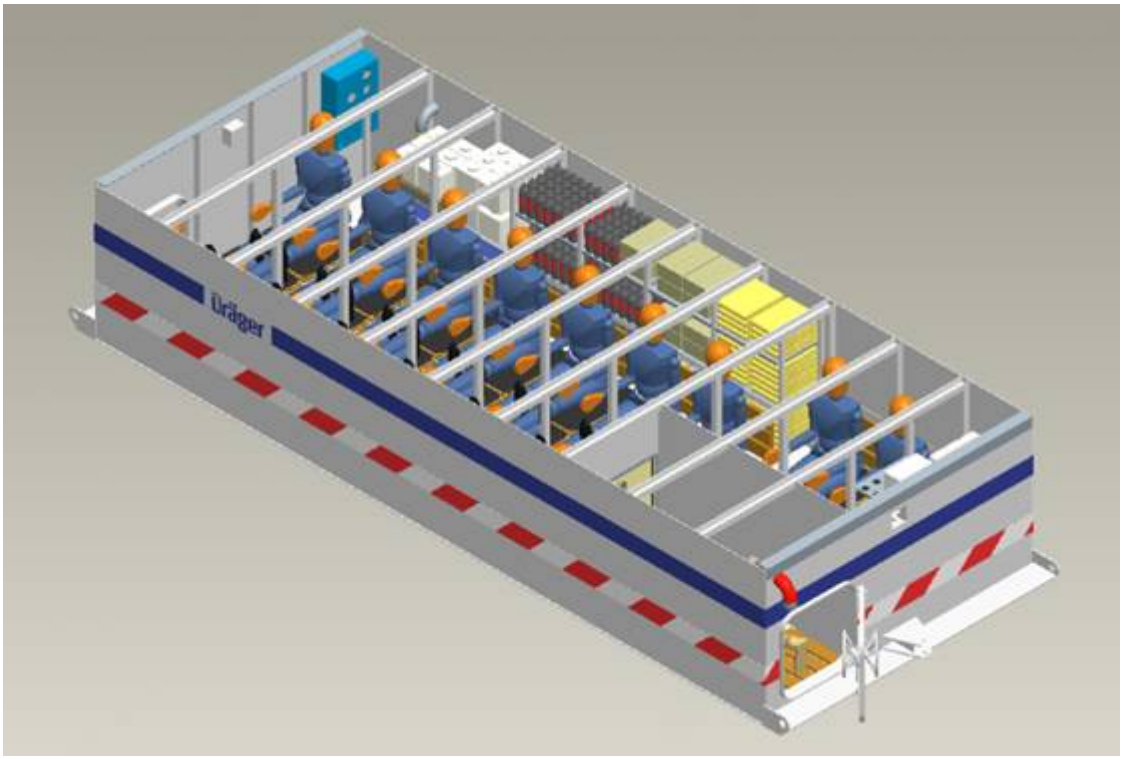

Figure D-2. Concept Illustration of Draeger Emergency Shelter

Table D-4. Kennedy Metal Products Inc., Kennedy Chamber

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Kennedy Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	100+hr (see O_2 consumption)
Initial Event Survival Standards		15 psi overpressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2 sec; flash fire of 300°F for 3 sec	Peak over-pressure 15 psi flash fire of 300°F for 3 sec (per NFPA-2113)	N/A	Blast test validated to 21 psi overpressure, also flash-fire test validated to 300°F
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/handling	Protect for normal handling and mine conditions	N/A	Steel skid, and tow hook attach plates. Draw bar tongue can be attached at either end.
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O_2 above 19.5%	N/A	Adjustable to fit number of occupants via O_2 cylinders, planned to be within required limits
	Carbon Dioxide Level	CO_2 maximum 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	Targeted for 0.5% CO_2 maximum, via LiOH curtains

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Kennedy Specifications
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	Monitored via gas analyzer, chamber air purged as necessary, temporary O_2 manifold masks used to augment protection
	Apparent Temperature	Maximum 95°F	Maximum 95°F	Maximum 95°F	Maximum 95°F	Theoretically kept below 95°F through a combination of radiation, and endothermic portion of LiOH reaction, validated by analysis and simulation
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous*	Not specified	N/A	0.8	Assumption not specified
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/min) at rest 4.2 CFH (1.982 L/ min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L /min/man)	N/A	1.32 CFH/man (0.62297 L/ min/man)	Performance can be 0.6L/man/hr, but design calculations used 0.5L/man/hr, so actual life support time may be 120 hr versus 100 h
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest 1/5 at moderate activity	Assumption not specified
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/Man (0.5097 L/ min/man)	Assumption not specified
	CO_2 Scrubbing Provisions	0.019 CFM/occupant (0.538 L/ min/occupant)*.	1.08 CFH/Man (0.5097 L/min/man)	N/A	LiOH curtains : 0.244 lb/Man/hr (or equivalent in soda lime etc.)	LiOH curtains : 0.244 lb/man/hr
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	Dedicated purge air cylinders, proprietary process -not dilution
	Design air flow to chamber	1.9 to 3.5 cfm/ occupant (53.8 to 107.6 L/ min/occupant)	Not specified	N/A	N/A	Not specified
	Chamber overpressure required (if the only system of gas incursion protection)	5 in of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	Overpressure is achieved via oxygen and make-up air addition, (O2 supply overcomes respiratory quotient volume loss). Actual chamber pressure not specified
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH_4	Gas analyzer provided, details not specified
Egress Provision To Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	(Additional information needed whether there is an airlock or not)

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Kennedy Specifications
Powered Subsystem Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	No powered subsystems
Water Provision		9 quart/occupant	Minimum 2.25 quart /person/ Day	Minimum 8 quart of water/Miner	N/A	Quantity not specified
Food Provision		6960 calories of Food/occupant	Minimum 2000 calories of food/person/day	Minimum 4000 calories of food/Miner	N/A	Quantity not specified
Human Waste Disposal		Minimum 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	Chemical toilet under one of the seats. Purged to exterior via valves
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	First aid kits supplied
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	Visual inspection for outer damage, inspection of gauge pressure (via windows in chamber), and tamper seal check
Inside Repairs by Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min.	Contain manufacturer recommended repair materials	N/A	Repair kit elements not specified
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	12 hr chemical snap sticks for 100 hr duration, plus MSHA approved 300 hr flashlights also.
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communications to the surface and mine's communication system	N/A	Permissible telephone supplied, through hull connectors
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	Chamber claimed to meet all specs.
Cooling Methods		Not specified	Not specified	N/A	N/A	No active cooling, but testing has shown LiOH may be endothermic in certain conditions. Testing has shown radiation cooling through chamber walls sufficient for WV mines)
Humidity Control		Not specified	Not specified	N/A	N/A	No active humidity control

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Kennedy Specifications
Seam Height Capability		Not specified	Not specified	N/A	N/A	"House" type ~5 ft inside height, "Skid" type ~24 in. inside height (Note the skid type may not meet MSHA PIB specs)
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	5 Steps after walk in: Purge with compressed air (if CO present), turn on O_2 valve to set point, turn on make-up air valve to set point, deploy lithium curtains, turn on gas analyzer
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	Not specified
Physical Testing Performed/ Planned		Not specified	May be required for application.	N/A	N/A	Performed: Full explosion, CO purge, chamber leakage, temp. rise, flash-fire, simulated CO_2 removal Planned: Full scale CO_2 absorption tests, heat transfer from actual chamber
No. of Occupants		N/A	N/A	N/A	N/A	10 - 33 man
Size and Weight		Not specified	Not specified	N/A	N/A	Approximately 21 ft L x 9 ft W x (24 in. to 60 in.)
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates.	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel.	N/A	N/A	Claimed 5 year no maintenance required, except visual inspection for outer damage, inspection of gauge pressure (via windows in chamber), and checking a tamper seal. A chamber has been set up on a mobile trailer fro training purposes.
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

Figure D-3. Kennedy Chamber

Table D-5. Strata Products (USA) Inc., Fresh Air Bay and Coal Mine Refuge Chamber

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Strata Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	96 hr, scalable
Initial Event Survival Standards		15 psi overpressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2 sec; flash fire of 300°F for 3 sec	Peak over-pressure 15 psi flash fire of 300F for 3 sec (per NFPA-2113)	N/A	Analysis shows survivable to 15 psi over-pressure and 300°F flash-fire in the un-deployed state
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/handling	Protect for normal handling and mine conditions	N/A	All rigid and stowed units have provisions for towing
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O_2 above 19.5%	N/A	Adjustable per no. of occupants (via O_2 cylinders) to be within required limits
	Carbon Dioxide Level	CO_2 max. 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	Can maintain CO_2 below 0.5%, via soda lime powered scrubber or optional LiOH curtains

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Strata Specifications
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	Monitored via gas analyzer. Chamber air purged as necessary
	Apparent Temperature	Maximum 95°F	Maximum 95°F	Maximum 95°F	Maximum 95°F	Cooling is a big issue per Strata. Chambers are sized with math model to naturally cool by radiation, conduction, convection., except for the rigid 20 to 24 man type, where chemical cooling packs are necessary
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous*	Not specified	N/A	0.8	Assumption not specified
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/ min) at rest 4.2 CFH (1.982 L/ min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L/ min/man)	N/A	1.32 CFH/Man (0.62297 L/ min/man)	Assumption is 0.4 to 0.5 L/min/man for calculations, but can perform at the MSHA 0.6 L/min /man level
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest 1/5 at moderate activity	Assumption not specified
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/Man (0.5097 L/min/ man)	Assumption not specified
	CO_2 Scrubbing Provisions	0.019 CFM/ occupant (0.538 L/min/ occupant)*.	1.08 CFH/Man (0.5097 L/min/man)	N/A	LiOH curtains: 0.244 lb/Man/hr (or equivalent in soda lime etc.)	Soda-lime cartridge system preferred, LiOH curtains offered as an option where heat build up and cost not a factor
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	3 x chamber volume, dedicated cylinders
	Design air flow to chamber	1.9 to 3.5 cfm/ occupant (53.8 to 107.6 L/ min/occupant)	Not specified	N/A	N/A	Airflow rate linked to No. of occupants on a sliding scale (need a minimum flow to operate scrubber blower). Flow rate through scrubber is crucial
	Chamber overpressure required (if the only system of gas incursion protection)	5 in. of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	Not specified
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH_4	Multi-gas analyzer supplied

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Strata Specifications
Egress Provision to Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	*Coal mine refuge (rigid)*: PVC curtain, not full airlock| *Fresh air bay(Infl):* Zippered tent airlock| *ESA/Strata type(Infl):* Zippered tent airlock
Powered Subsystem, Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	Permissible compressed air motor
Water Provision		9 quart/occupant	Minimum 2.25 quart /person/ Day	Minimum 8 quart of water/Miner	N/A	Quantity not specified
Food Provision		6960 calories of Food/occupant	Minimum 2000 calories of food/person/day	Minimum 4000 calories of food/Miner	N/A	Quantity not specified
Human Waste Disposal		Min 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	Chemical toilets, waste expelled via valves and airlocks
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	First aid kits supplied
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	(Additional information needed access)
Inside Repairs by Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min.	Contain manufacturer recommended repair materials	N/A	For airbeam/tent types there is a special device to seal holes quickly, and a manual pump to re-inflate.
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	Not specified
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communications to the surface and mine's communication system	N/A	Not specified
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	Requirements will be met

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Strata Specifications
Cooling Methods		Not specified	Not specified	N/A	N/A	*Coal mine refuge (rigid):* 8 to 16 man, sized for no cooling, 20 to 24 man type has chemical cooling packs, (cool at 40 BTW /hr) *Fresh air bay(Infl):* Sized for no cooling *ESA/Strata type(Infl):* Sized for no cooling
Humidity Control		Not specified	Not specified	N/A	N/A	Condensed moisture is collected via channels and super-wicking absorbents, and expelled with toilet waste
Seam Height Capability		Not specified	Not specified	N/A	N/A	*Coal refuge chamber (rigid):* 42 in. + *Fresh air bay(Infl):* 32 in. stowed (tent 30 in. and up) *ESA/Strata type(Infl):* Approximately 35 in. stowed (tent 35 in. and up)
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	*1) Fresh Air Bay (Infl): 3 Steps to deploy:* Release tent door, Turn on inflation valve breathable air, ((pull out accordion tent manually for non-airbeam type), Turn on purge air if CO present. *5 Steps after walk in:* Turn on O_2 to set point, turn on airflow for CO_2 scrubber to set point, load soda lime "sock" cartridges into scrubber tank. Purge air from inside if necessary. Turn on gas analyzer. *2) Coal Mine Refuge Chamber: 5 Steps after walk in:* Turn on O_2 to set point, turn on airflow for CO_2 to set point, load soda lime "sock" cartridges into scrubber tank, purge air from inside if necessary, turn on gas analyzer.

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Strata Specifications
Human Intervention Required to Operate (continued)						*3) ESA/Strata 25 Miner Unit: 3 Steps to deploy:* Release tent door, Turn on inflation valve breathable air, ((pull out accordion tent manually for non-airbeam type), Turn on purge air if CO present. *5 Steps after walk in:* Turn on O_2 to set point, turn on airflow for CO_2 scrubber to set point, load soda lime "sock" cartridges into scrubber tank. Purge air from inside if necessary. Turn on gas analyzer
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	Number is not specified, (they have developed a figure for this through calculations and work, which they use for all shelter designs.)
Physical Testing Performed/ Planned		Not specified	May be required for application	N/A	N/A	*Performed:* Temperature rise, CO testing, variety of Australian tests on rigid type -no blast or fire testing done. *Planned:* Not specified
No. of Occupants		N/A	N/A	N/A	N/A	*Coal refuge chamber (rigid):* 8, 16, 24 *Fresh air bay (Infl):* 10, 16, 20 *ESA/Strata type (Infl):* 25 man
Size and Weight		Not specified	Not specified	N/A	N/A	*Coal refuge chamber (rigid):* 7 ft W x (42 in. to 60 in.)H x 12 ft to 22 ft L, weight: 20,000 lb stocked *Fresh Air Bay (stowed box):* Approximately 32 in. skid H, (tents 30 in. minimum, no maximum), Weight: approximately 14,000 lb stocked *ESA/Strata (Stowed box):* Approximately 35 in..skid H, Weight: approximately 16,000 lb stocked

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Strata Specifications
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates.	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel.	N/A	N/A	No special maintenance specified other than checking cylinders/chemical shelf life/physical check of container. Strata say historically with Army inflatables etc., no special inspection has been required.
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

Figure D-4. Strata Coal Mine Refuge Chamber

Figure D-5. Strata Fresh Air Bay

Table D-6. Modern Mine Safety Supply, Emergency Refuge Shelter

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Modern Mine Safety Supply "Emergency Refuge Shelter" Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	96 hr +
Initial Event Survival Standards		15 psi over-pressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2 sec; flash fire of 300°F for 3 sec	Peak overpressure 15 psi flash fire of 300°F for 3 sec (per NFPA-2113)	N/A	Rigid steel chamber, 0.25 in. steel plate with external steel ribs. Analysis shows survival at 15 psi peak overpressure, and 300°F Flash-fire
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/handling	Protect for normal handling and mine conditions	N/A	Skid mounted, heavily reinforced with external ribs, can be towed
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O_2 above 19.5%	N/A	"RANA Refuge one" air system will maintain O_2 above 19.5%
	Carbon Dioxide Level	CO_2 maximum 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	Below 0.5%
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	Below 50 ppm
	Apparent Temperature	Maximum 95° F	Maximum 95°F	Maximum 95°F	Maximum 95°F	95°F or better
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous*	Not specified	N/A	0.8	Assumption not specified
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/ min) at rest 4.2 CFH (1.982 L/ min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L/min/ man)	N/A	1.32 CFH/Man (0.62297 L/min/ man)	Assumption not specified
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest 1/5 at moderate activity	Assumption not specified
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/Man (0.5097 L/min/ man)	Assumption not specified
	CO_2 Scrubbing Provisions	0.019 CFM/ occupant (0.538 L/min/ occupant)*.	1.08 CFH/Man (0.5097 L/min/ man)	N/A	LiOH curtains : 0.244 lb/man/hr (or equivalent in soda lime etc.)	18 Cartridges of soda lime provided, each 18 in. x 11 in. x 9 in.

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Modern Mine Safety Supply "Emergency Refuge Shelter" Specifications
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	5 min purge possible after entry, via 2 C/A cylinders, size T. Approximately 330 ft^3 each cylinder. Purge noise is muffled.
	Design air flow to chamber	1.9 to 3.5 cfm/ occupant (53.8 to 107.6 L/ min/occupant)	Not specified	N/A	N/A	0.5 to 0.8 liters /min of O_2 into chamber, -which provides the positive pressure in chamber (injected into blower air stream)
	Chamber overpressure required (if the only system of gas incursion protection)	5 in. of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	Excess O_2 flow into chamber provides the positive pressure
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH_4	Inside/outside monitoring via multi-gas analyzer, CO, CO_2, O_2, CH_4
Egress Provision to Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	Airlock, has room for stretcher entry
Powered Subsystem, Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	Circulating air blower for CO_2 scrubber is battery powered, intrinsically safe 24 volt system. No out gassing. (pending W.VA approval)
Water Provision		9 quart/occupant	Minimum 2.25 quart/person/ day	Minimum 8 quart of water/ Miner	N/A	Water pouches with meal kits, equivalent of 37.8 quart per miner, plus 14 additional quart in containers. 5 year shelf life in this packaging.
Food Provision		6960 calories of Food/occupant	Minimum 2000 calories of food/person/ day	Minimum 4000 calories of food/Miner	N/A	16 x 72 hr meal kits, each kit has 9,000 to 10,000 calories, plus 16 additional 3600 cal. Kits. 5 year packaging shelf life

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Modern Mine Safety Supply "Emergency Refuge Shelter" Specifications
Human Waste Disposal		Min 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	Dry chemical toilet provided, PETT system with WAGBAGS - contain sanitizer, toilet paper, zip-close bag and decay catalyst. Bags are passed through a airlock to an exterior chamber. Toilet is portable, folds up, weighs 7 lb
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	Meets requirements, plus additional compresses, splints, cold packs, and rubber blanket
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	Maintenance/ Inspection schedule is charted: daily, monthly, semi annual, and annual checks.
Inside Repairs by Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min.	Contain manufacturer recommended repair materials	N/A	Repair kit in protected container, includes caulking gun and silicone, four rolls duct tape, large patches of rubber sheet
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	Provided
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communications to the surface and mine's communication system	N/A	Secure storage space provided for a future approved comm. System
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	Full approvals except battery blower system (pending review)

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Modern Mine Safety Supply "Emergency Refuge Shelter" Specifications
Cooling Methods		Not specified	Not specified	N/A	N/A	No specific cooling methods. RANA refuge one system has an airflow that aids cooling. Radiation from chamber. Analysis shows adequate for W.VA mines
Humidity Control		Not specified	Not specified	N/A	N/A	RANA refuge one has a desiccant as part of the system
Seam Height Capability		Not specified	Not specified	N/A	N/A	Current design high coal only - walk in. MMSS say that the RANA refuge one air system can be re-configured for low coal design.
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	*5 Steps after walk in:* Purge with dedicated compressed air (if CO present), load soda lime cartridges into RANA refuge one scrubber, turn on battery powered blower to set point, turn on O_2 flow to set point, turn on gas analyzer
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	Not specified
Physical Testing Performed/ Planned		Not specified	May be required for application.	N/A	N/A	*Performed:* Man testing of RANA Refuge one air system in Canada. *Planned:* Not specified
No. of Occupants		N/A	N/A	N/A	N/A	16 man
Size and Weight		Not specified	Not specified	N/A	N/A	(Additional information needed)

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	Modern Mine Safety Supply "Emergency Refuge Shelter" Specifications
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates.	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel.	N/A	N/A	Maintenance/ Inspection schedule is charted: daily, monthly, semi annual, and annual checks. Recommend replace batteries at 2 years, replace soda lime canisters at 3 years, and replace (test) cylinders every 5 years
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

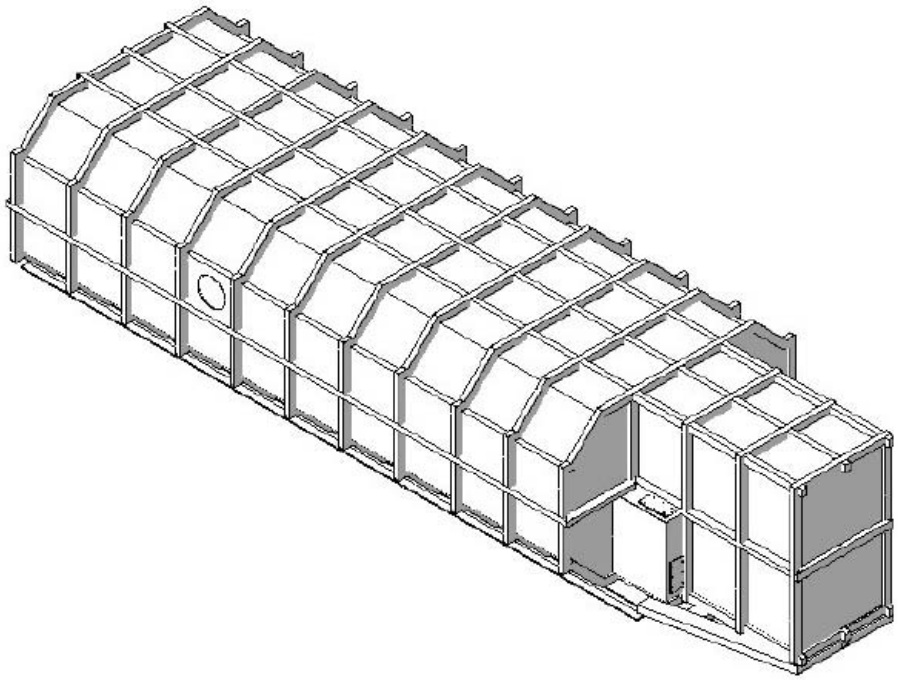

Figure D-6. Concept Illustration of MMSS Emergency Refuge Shelter

Table D-7. LifePod

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	LifePod Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	96 hr, more if less miners than capacity
Initial Event Survival Standards		15 psi overpressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2 sec; flash fire of 300°F for 3 sec	Peak overpressure 15 psi flash fire of 300°F for 3 sec (per NFPA-2113)	N/A	15 psi, 300°F Flash-fire, by analysis
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/handling	Protect for normal handling and mine conditions	N/A	On skid, 27 in. total height, Steel container
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O_2 above 19.5%	N/A	Supply is pure breathable air, not recycled, exhaled to refuge
	Carbon Dioxide Level	CO_2 maximum 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	Air is not recycled, no CO_2 scrubbing needed.

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	LifePod Specifications
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	Sealed face mask system, no outside contaminants unless mask seal fails
	Apparent Temperature	Maximum 95°F	Maximum 95°F	Maximum 95°F	Maximum 95°F	Same as ambient, miners are exposed
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous*	Not specified	N/A	0.8	Assumption not specified
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/ min) at rest 4.2 CFH (1.982 L/ min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L/min/ man)	N/A	1.32 CFH/Man (0.62297 L/min/ man)	Assumption not specified
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest 1/5 at moderate activity	Assumption not specified
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/man (0.5097 L/min/ man)	Assumption not specified
	CO_2 Scrubbing Provisions	0.019 CFM/ occupant (0.538 l/min/ occupant)*.	1.08 CFH/man (0.5097 L/min/ man)	N/A	LiOH curtains: 0.244 lb/Man/hr (or equivalent in soda lime etc.)	None necessary, face mask breathing, CO_2 exhaled to outside. Could provide LiOH curtains as option and use closed chamber, but may be redundant, in discussion with WV now
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	None necessary, open shelter, no roof.
	Design air flow to chamber	1.9 to 3.5 cfm/ occupant (53.8 - 107.6 L/ min/occupant)	Not specified	N/A	N/A	N/A
	Chamber overpressure required (if the only system of gas incursion protection)	5 in. of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	N/A
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH^4	Multi-gas analyzer provided with system
Egress Provision to Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	N/A
Powered Subsystem, Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	No subsystem
Water Provision		9 quart/occupant	Minimum 2.25 quart/ person/day	Minimum 8 quart of water/Miner	N/A	Will meet requirements

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	LifePod Specifications
Food Provision		6960 calories of food/occupant	Minimum 2000 calories of food/person/ day	Minimum 4000 calories of food/Miner	N/A	Planned to be liquid meals, like Ensure etc., calorie count will meet requirements. Food imbibed through mask system.
Human Waste Disposal		Min 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	Chemical toilet provided, bags within a bigger sealed bag
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	Will meet requirements
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	Two gauges to check air supply, on central refill port accessible from outside container. Maska era in ziplock bags, protected for hygiene. Only need hydrostatic cylinder tests every 5 years.
Inside Repairs By Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min.	Contain manufacturer recommended repair materials	N/A	(Additional information needed)
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	Chemical snap sticks, hand pump flashlights. Could also add permissible battery LED lights deployed by magnets to roof bolts
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communications to the surface and mine's communication system	N/A	May provide the masks with the communication option for each other. No system planned yet for surface comm's
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	Yes, (except masks from Italy may need special approval by NIOSH)
Cooling Methods		Not specified	Not specified	N/A	N/A	None, ambient conditions
Humidity Control		Not specified	Not specified	N/A	N/A	Desiccant may be provided to help with humidity in area
Seam Height Capability		Not specified	Not specified	N/A	N/A	Designed for low coal, system container is 27 in. high, any seam height ok

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MSHA PIB Recommendations (PIB 07-03, Breathable Air)	LifePod Specifications
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	*4 Steps to operate:* Open container, retrieve masks, turn on air supply, don masks. There are folding chairs stored in container or pads to sit on.
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	Open roofed shelter, spacing limited by manifold feed length
Physical Testing Performed/ Planned		Not specified	May be required for application.	N/A	N/A	(Additional information needed)
No. of Occupants		N/A	N/A	N/A	N/A	4-man , or 16-man system
Size and Weight		Not specified	Not specified	N/A	N/A	Approximately 8 ft W x 13 ft L x 27 in. H, -a mine scoop can move it. Weight approximately5 to 6 tons stocked.
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates.	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel.	N/A	N/A	(Additional information needed)
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

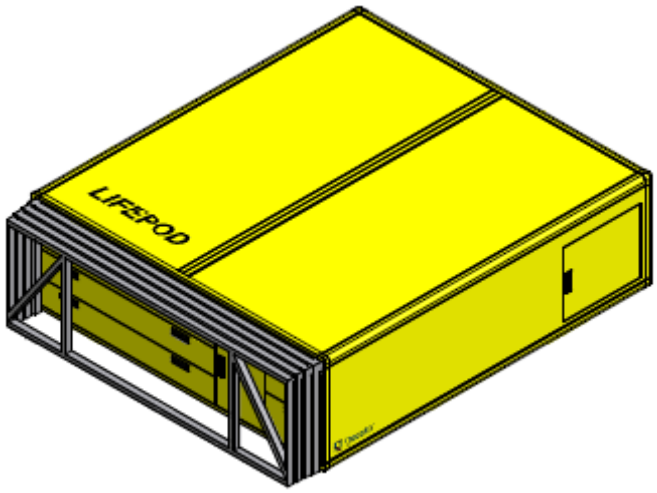

Figure D-7. Concept Illustration of LifePod System

Table D-8. Mine Lifeline

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MS HA PIB Recommendations (PIB 07-03, Breathable Air)	Mine Lifeline Specifications
Life Support Timespan Capability		96 hr	Minimum 48 hr	Minimum 48 hr	Minimum 96 hr	96 hr
Initial Event Survival Standards		15 psi over-pressure for 0.3 sec; flash fire of 300°F for 3 sec	15 psi overpressure for 0.2 sec; flash fire of 300°F for 3 sec	Peak overpressure 15 psi flash fire of 300°F for 3 sec (per NFPA-2113)	N/A	Relies on constructed stopping(s)
Handling and Transport Readiness		Universal Refuge Bulkhead design utilizing reusable, modular components	Safely moveable, withstand collisions during transport/ handling	Protect for normal handling and mine conditions	N/A	More information required
Atmosphere Management Capability	Oxygen Level	O_2 between 18.5% to 23%	O_2 between 18.5% to 23%	O_2 above 19.5%	N/A	O_2 cylinders. (Additional information needed)
	Carbon Dioxide Level	CO_2 maximum 0.5% with excursions to 1%	CO_2 1.0% or less with excursions not to exceed 2.5%	CO_2 below 0.5%	N/A	LiOH curtaines. (Additional information needed)
	Carbon Monoxide Level	CO 25 ppm or less	CO 25 ppm or less after 20 min	CO below 50 ppm	CO below 25 ppm	Purgeable airknife manway, compressed air cylinders. (Additional information needed)
	Apparent Temperature	Maximum 95°F	Maximum 95°F	Maximum 95°F	Maximum 95°F	(Additional information needed)
	Respiratory Quotient (CO_2/O_2)	0.75 at rest 0.9 moderate 1.0 very vigorous	Not specified	N/A	0.8	(Additional information needed)

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MS HA PIB Recommendations (PIB 07-03, Breathable Air)	Mine Lifeline Specifications
	Average Oxygen Consumption Rate	0.6 CFH (0.283 L/ min) at rest 4.2 CFH (1.982 L/ min) moderate activity 6 CFH (2.832 L/ min) very vigorous*	1.32 CFH/Man (0.62297 L/ min/man)	N/A	1.32 CFH/Man (0.62297 L/min/ man)	(Additional information needed)
	Assumed Breathing Rate	4/5 at rest 1/5 at moderate activity*	Not specified	N/A	4/5 at rest 1/5 at moderate activity	(Additional information needed)
	Average Carbon Dioxide Generation Rate	1.117 CFH/man (0.527 L/min)*	Not specified	N/A	1.08 CFH/Man (0.5097 L/min/ man)	(Additional information needed)
	CO_2 Scrubbing Provisions	0.019 CFM/ occupant (0.538 L/min/ occupant)*.	1.08 CFH/man (0.5097 L/min/ man)	N/A	LiOH curtains : 0.244 lb/Man/hr (or equivalent in soda lime etc.)	LiOH curtains. (Additional information needed)
	Chamber Purge Volume Requirement	Not specified	Not specified	N/A	3 x Chamber volume	(Additional information needed)
	Design air flow to chamber	1.9 TO 3.5 cfm/ occupant (53.8 - 107.6 L/ min/occupant)	Not specified	N/A	N/A	N/A
	Chamber overpressure required (if the only system of gas incursion protection)	5 in of water (~0.18 psi)*	0.25 psi above mine atmospheric pressure	N/A	N/A	(Additional information needed)
Gas Monitoring		O_2, CO, CO_2 inside; O_2, CO, CH_4 outside	Monitor inside and out O_2, CO, CO_2, and CH_4	Monitor inside and out: O_2 and CO	Monitor O_2, CO, CO_2, and CH^4	(Additional information needed)
Egress Provision To Maintain Air Quality		All chambers to have airlocks	Airlock or positive overpressure inside	Provide entry and exit method that maintains inside atmosphere integrity	N/A	Airknife manway
Powered Subsystem, Intrinsic Safety		Must be permissible system	Must be intrinsically safe	MSHA certified intrinsically safe power, if required	N/A	N/A
Water Provision		9 quart/occupant	Minimum 2.25 quart/ person/day	Minimum 8 quart of water/Miner	N/A	(Additional information needed)
Food Provision		6960 calories of Food/occupant	Minimum 2000 calories of food/person/day	Minimum 4000 calories of food/Miner	N/A	(Additional information needed)
Human Waste Disposal		Min 2 toilets Add 1 toilet for every 8 occupants over 16 occupants 2 gal waste storage/occupant	Provide a means to contain human waster and minimize odors	Provide means for human waste disposal outside of chamber	N/A	(Additional information needed)

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MS HA PIB Recommendations (PIB 07-03, Breathable Air)	Mine Lifeline Specifications
First Aid Provision		One standard MSHA first aid kit/10 occupants	Provide first aid supplies	Provide first aid kit, (per WV Code Chapter 22A, article 2-59(3)(b)	N/A	(Additional information needed)
Inspection Provision		After initial installation, annually thereafter, after relocation, after mine event, pre-shift checks	Pre-shift checks for damage, tamper resistant seals, activation mechanism, O_2 or air availability	Provide means for inspection of shelter and contents	N/A	(Additional information needed)
Inside Repairs By Occupants Provision		Repair materials specified	Provide means to repair. Ensure routine repairs can be completed within 10 min.	Contain manufacturer recommended repair materials	N/A	(Additional information needed)
Occupant Indicator Light Provision		Not specified	Not specified	Provide battery powered strobe light visible from outside indicating occupancy	N/A	(Additional information needed)
Surface Communications Provision		Two way communications with mine areas outside refuge and with surface	Provide two way communication	Provide provisions for communications to the surface and mine's communication system	N/A	(Additional information needed)
MSHA Approval of All Items and Materials		Per existing MSHA regulations	Required	Provide proof of approval for all items and materials subject to MSHA approval	N/A	(Additional information needed)
Cooling Methods		Not specified	Not specified	N/A	N/A	(Additional information needed)
Humidity Control		Not specified	Not specified	N/A	N/A	(Additional information needed)
Seam Height Capability		Not specified	Not specified	N/A	N/A	(Additional information needed)
Human Intervention Required to Operate		Not specified	Not specified	Not specified	Not specified	(Additional information needed)
Individual occupant space allowance		Minimum 15 ft^2/man	Minimum 15 ft^2/man	N/A	N/A	(Additional information needed)
Physical Testing Performed/ Planned		Not specified	May be required for application.	N/A	N/A	(Additional information needed)
No. of Occupants		N/A	N/A	N/A	N/A	(Additional information needed)
Size and Weight		Not specified	Not specified	N/A	N/A	8 ft x 12 ft x 42 in. H, <4500 lb, Airknife: 400 lb

Category	Sub-Category	Foster-Miller Recommendations	MSHA Proposed Rule; Refuge Alternatives for Underground Coal Mines	WV Technical Rules for Approval	MS HA PIB Recommendations (PIB 07-03, Breathable Air)	Mine Lifeline Specifications
Maintenance and Training		Training for all miners on shelter use. Regular checks of the communication system and life support elements. Inventory lists with expiry dates.	Maintenance and training records required. Detailed maintenance and training requirements for users and inspection and maintenance personnel.	N/A	N/A	(Additional information needed)
*Value determined from Foster-Miller Inc. 1983 Report, "Development of Guidelines for Rescue Chambers, Vol. 1" [R5-5]						

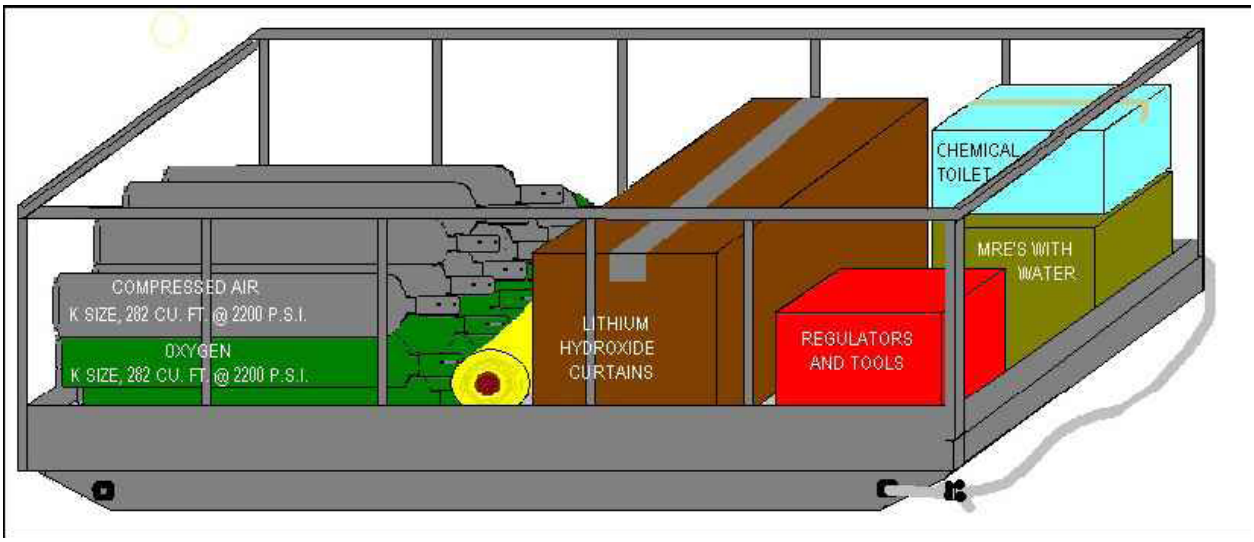

Figure D-8. Concept Illustration of Mine Lifeline System