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MINE SAFETY AND HEALTH ADMINISTRATION  
COAL MINE SAFETY AND HEALTH

REPORT OF INVESTIGATION  
Fatal Underground Coal Mine Explosion  
January 2, 2006  
Sago Mine, Wolf Run Mining Company  
Tallmansville, Upshur County, West Virginia  
ID No. 46-08791  
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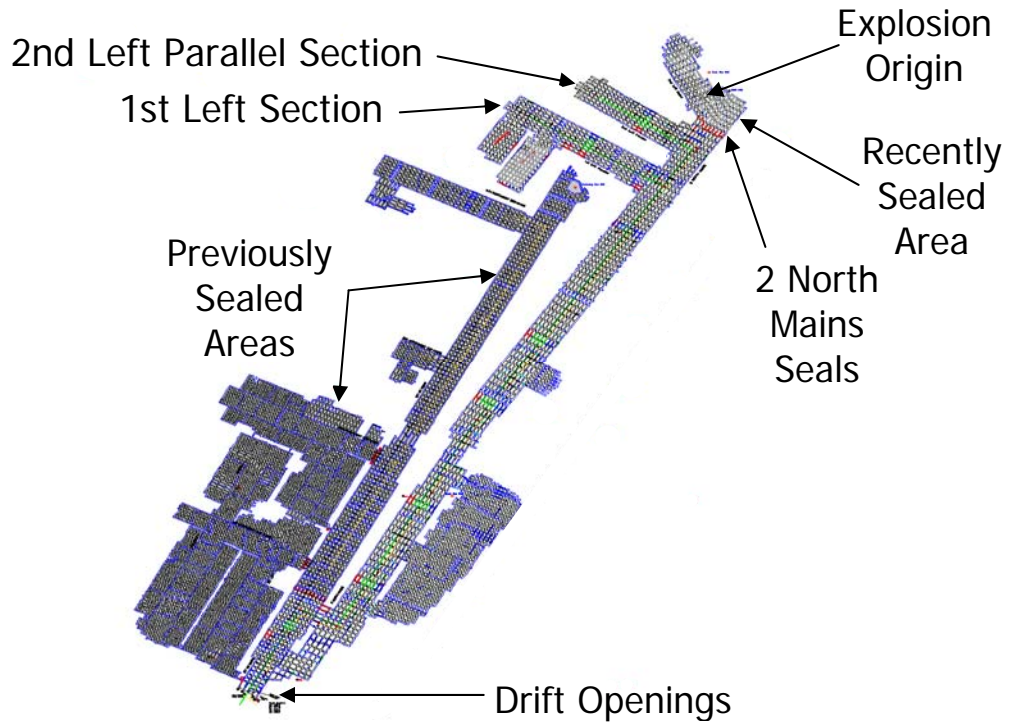
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# SAGO MINE





## OVERVIEW

On January 2, 2006, an explosion occurred at approximately 6:26 a.m. in Wolf Run Mining Company's Sago Mine. At the time of the explosion, 29 miners were underground. Twelve miners lost their lives, and one was seriously injured. The explosion occurred in by the 2 North Mains seals, and destroyed all ten of the seals used to separate the area from the active portion of the mine.

The weather conditions at the mine were unseasonably warm with the temperature near 45 degrees Fahrenheit (F). A storm, accompanied by heavy rain, thunder and lightning, was in the area. Before entering the mine, some Sago miners saw lightning strikes near the property.

A preshift examination of the mine had been conducted. One mine examiner remained underground. The 2nd Left Parallel crew and another miner entered the mine at about 6:00 a.m. The 1st Left crew and three other miners entered the mine shortly thereafter. The 2nd Left Parallel crew arrived on their working section, and the 1st Left mantrip arrived at the 1st Left switch. Shortly thereafter, an explosion occurred.

One miner died of carbon monoxide (CO) poisoning shortly after the explosion. The 2nd Left Parallel miners' attempt to evacuate was unsuccessful, and they barricaded themselves on the 2nd Left Parallel section. All other miners eventually evacuated the mine.

Mine management officials entered the mine in an attempt to assess the situation. The 1st Left Foreman remained underground and eventually joined this group. They found that the explosion damaged ventilation controls. In an effort to reach the missing miners, they attempted to restore ventilation, using temporary ventilation controls. They were unable to clear the smoke and gases, and eventually ended their rescue attempt and evacuated the mine.

Federal and state agencies responded to the accident. Mine rescue teams were organized, a command center was established, and a rescue effort was initiated. Entry into the mine was delayed because of elevated levels of CO and methane. Preparations were started to drill a borehole into the 2nd Left Parallel section for sampling and communications purposes.

Rescue teams entered the mine after the concentration of gases stabilized. They found the first victim on January 3, near the 2nd Left Parallel track switch. Later that evening, rescue teams advanced into the 2nd Left Parallel section where twelve miners were found behind a barricade. One miner was found alive. He was rescued and transported to a hospital. On January 4, the 12 victims were

recovered from the mine. A list of the deceased and injured miners is contained in Appendix A.

Working with the West Virginia Office of Miners' Health, Safety and Training (WVMHS&T), the mine operator, and miners' representatives, the Mine Safety and Health Administration (MSHA) launched an investigation into the events surrounding the fatal accident. The investigative team interviewed people with knowledge of the mine or the accident. Investigators mapped the mine, reviewed mine records and gathered relevant physical evidence from underground. The evidence was evaluated.

Investigators determined that methane began to accumulate within an area which had previously been mined and then sealed with 40 inch thick Omega block seals. The explosion occurred within the sealed area and destroyed the seals. This caused portions of the mine to fill with toxic levels of CO. At MSHA's request, the National Institute for Occupational Safety and Health (NIOSH) conducted a full-scale testing program designed to determine the strength of the Omega block seals and to gather information about explosions in sealed areas. The mine operator failed to build the seals in accordance with the approved plan. However, the testing showed that the seals, as built at the mine, would likely have withstood pressures of 20 pounds per square inch (psi), as required by regulation. The explosion in the mine is believed to have generated pressures in excess of 93 psi. The discrepancies between the actual seal construction and the approved plan, as well as all other non-contributory conditions observed during the investigation, were cited under a separate inspection activity.

MSHA collected Self-Contained Self Rescuer units (SCSRs) used by the miners, and tested them. The mine operator did not keep adequate records on all of the units, and one unit was out-of-date. Some of the miners had trouble donning their SCSRs and breathing through them. However, testing indicated that the units produced oxygen as intended.

Investigators determined that coal dust did not play a major role in the explosion. Potential ignition sources were investigated. There was no evidence that cutting, welding, mining operations, smoking, or spontaneous combustion were involved in the ignition. Electrical systems and equipment were also ruled out as possible ignition sources. Although a roof fall cannot be definitively excluded as a potential ignition source, it is a highly unlikely ignition source.

Lightning strikes were recorded near the mine at approximately the same time as a seismic event occurring in the area and the initial alarm from the mine's atmospheric monitoring system (AMS). MSHA contracted with Sandia Corporation, the operator of the Sandia National Laboratories (Sandia), to

perform modeling and testing to ascertain if it was possible for lightning to cause electrical energy to enter the mine and cause an explosion. Sandia determined that a lightning strike could create enough energy in the sealed area to initiate an arc. Lightning has been determined to be the most likely ignition source.

## GENERAL INFORMATION

The Sago Mine is located near Tallmansville, Upshur County, West Virginia. The mine opened in 1999 as the Spruce No. 2 Mine operated by BJM Coal Company. The mine changed ownership in 2002. Anker West Virginia Mining Company, Inc., a subsidiary of Anker Group, Inc., acquired the company and renamed the mine as Sago Mine in 2003. International Coal Group, Inc. (ICG) acquired Anker Group, Inc. in 2005. The Anker West Virginia Mining Company, Inc. was renamed the Wolf Run Mining Company in late 2005.

Principal Officers of ICG were Bennett K. Hatfield, President and Chief Executive Officer; Oren E. (Gene) Kitts, Senior Vice President, Mining Services; Samuel R. (Sam) Kitts, Senior Vice President of Operations; and Timothy Martin, Corporate Director of Health and Safety. ICG owns and operates a number of mining properties throughout the United States.

The management structure at the mine was similar to that traditionally found at coal mines throughout the United States. The direct line of supervision consisted of mine superintendent, mine foreman and foremen. Mine Superintendent Jeffrey Toler was head of the on-site mine management organization at the mine and was responsible for the overall operation of the mine. Mine Foreman Carl Crumrine was responsible for all underground activities including countersigning various mine record books. Safety Director James Schoonover was responsible for mine safety issues and training, as well as accompanying state and federal inspectors while on mine property. Maintenance Superintendent Denver Wilfong was in charge of all electrical and equipment related issues. A number of shift foremen, section foremen and outby foremen were responsible for coal production and general support operations.

The mine opened into the Middle Kittanning coal seam through five drift openings. The drift openings were located in a box cut where the overburden material was removed down to the coal seam level. Drift openings were numbered with the No. 1 Drift Opening on the extreme left side. The mine fan was located in the No. 5 Drift Opening on the extreme right side of the highwall. The developing entries were numbered separately from the drift openings, from left to right, with the No. 1 entry on the extreme left side. Mine personnel identified locations in the mine by the numbered crosscut along with the corresponding main belt, for example, 34 Crosscut, No. 2 Belt. Coal was produced from the 1st Left and 2nd Left Parallel sections. The majority of the 1st NE Mains was sealed. The 2nd Left Mains were also sealed. A map of the mine

is illustrated in Figure 1 to provide an overview of the mine. A detailed map of the mine is shown in Appendix B.

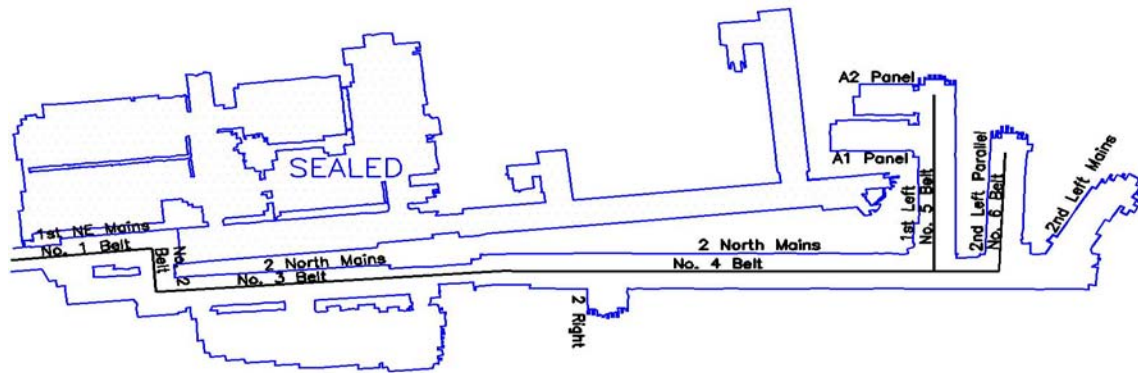


Figure 1 - Sketch of Sago Mine

The mine work schedule consisted of two overlapping 10 hour shifts beginning at 6:00 a.m. and 3:00 p.m. and one maintenance shift beginning at 12 midnight, Monday through Thursday. The weekend schedule (Friday, Saturday and Sunday) was composed of two overlapping 13 ½ hour production shifts, and one 8 hour maintenance shift. Coal was produced from two sections. Two remote-controlled, continuous mining machines and two twin boom roof-bolting machines operated in each of the 1st Left and 2nd Left Parallel sections. There were three electrically powered shuttle cars located in 1st Left and four in 2nd Left Parallel. The two continuous mining machines in each section were not operated simultaneously. One mining machine completed a cut sequence and was idled. The other mining machine proceeded to cut another sequence.

Sections were developed by advancing eight entries. The approved roof control plan allowed for main entries, sub-main entries and rooms to be developed 20 feet wide, on centers from 48 feet to 110 feet. Crosscuts could range from 54 feet to 140 feet centers in the mains, 48 feet to 140 feet centers in the sub-mains and 40 feet to 140 feet centers in rooms. The average mining height was approximately 7 feet.

In addition to the normal mining development, bottom mining was conducted in some areas of the mine. The bottom mining was the removal of the lower bench of the Middle Kittanning coal seam. When mining was completed in an area, or adverse conditions were encountered that ended development, this method was used to maximize coal yield. Because of the extreme heights that would have been created during initial development, the bottom portion of the coal seam was not mined at that time. During and after removal, no miner was permitted in the

mined out area. This precaution eliminated exposure to high, unsupported coal ribs. Rock dust was applied during initial development as required. Additional rock dust was not applied in areas that had been bottom mined. A portion of the sealed 2nd North Mains and 2nd Left Mains area had been bottom mined. The A-1 and A-2 Panels off of 1st Left were also bottom mined.

Verizon provided telephone service to the surface buildings. The underground mine communication system consisted of pager phones, trolleyphones and wireless handheld two-way radios.

Battery-powered track mounted personnel carriers (mantrips) and locomotives were used to move men and materials throughout the mine. The mine dispatcher was located in an office on the surface. The dispatcher directed and monitored all traffic entering, traveling throughout, and exiting the mine. He also monitored an AMS that consisted of sensors placed throughout the mine that relayed information to a central computer. This system displayed a continuous readout of CO levels at each sensor located along each belt conveyor entry, belt startup, belt shutdown and mine power status. The Mine Emergency Evacuation and Firefighting Program of Instruction designated the dispatcher as the responsible person in the event of an emergency.

A large portion of the mine was wet, and pumps controlled the water accumulations. Coal was transported from the working sections to the surface by a series of conveyor belts, and was then loaded onto trucks, transported to a nearby cleaning plant, and processed. In 2005, the mine produced approximately 1,700,000 tons of raw materials, which resulted in 507,775 tons of clean coal. This resulted in a recovery ratio of approximately 30 percent. Reportedly, this ratio did not change significantly during bottom mining.

A blowing fan, located on the surface, ventilated the mine. The mine fan produced approximately 146,000 cubic feet per minute (cfm) of air. Mine inspection records in October 2005 indicated that the mine liberated approximately 90,500 cubic feet per day (cfd) of methane. A single split ventilation system was used in each of the two sections. Intake air was typically directed through the Nos. 7 and 8 entries and returned out the Nos. 1 and 2 entries. The Nos. 3 through 6 entries were ventilated with intake air generally traveling in the outby direction. Air lock doors were installed in the track entry, one door was located between 8 and 9 Crosscuts, No. 1 Belt and another door was located between 12 and 13 Crosscuts, No. 1 Belt. These doors allowed for the passage of men and materials without disrupting the air current. To accomplish this, only one door was opened at a time.

The mine employed approximately 135 underground miners and six surface miners. At the time of the accident, the miners were not represented by a labor

union for collective bargaining purposes. During the investigation, two separate miners' representative groups were selected to represent the miners. One group of miners selected the United Mine Workers of America (UMWA) and the other selected a group of Sago miners. Both groups participated in portions of the onsite investigation.

Table 1 shows the Fatal and Non-Fatal Days Lost (NFDL) accident incidence rates for the mine along with the comparable national rates for all underground coal mines, for years 2004 and 2005.

**Table 1 - Accident Incidence Rates**

<b>Calendar Year</b>	<b>Incidence Rate Sago Mine</b>	<b>Incidence Rate National</b>	<b>National All Incident Rate</b>
2004	NFDL/Fatal 15.90/0.00	NFDL/Fatal 5.98/0.04	National/Sago 8.42/19.88
2005	NFDL/Fatal 10.22/0.00	NFDL/Fatal 5.42/0.03	National/Sago 7.71/12.41

MSHA completed its last regular health and safety inspection of Sago on September 30, 2005. MSHA started a new inspection on October 3, 2005. The inspection was ongoing at the time of the accident.

Table 2 summarizes MSHA enforcement actions at the mine in 2005 prior to the accident, and references the number of citations issued to the operator under provisions of the Federal Mine Safety and Health Act of 1977.

**Table 2 - Enforcement Actions in 2005**

<b>Type Enforcement Action</b>	<b>Number Initiated - 208 (2 vacated actions excluded)</b>
104(a) non-S&S citation	85
104(a) S&S citation	96
104(b) order	1
104(d)(1) citation	1
104(d)(1) order	2
104(d)(2) order	14
107(a) order	1
314 (b) safeguard	5
103(k) order	3

At the time of the accident, eight citations had not been terminated. They were not associated with the accident. Three of the citations involved tunnel liners, two were in the primary escapeway, two were electrical and one was for guarding. These violations occurred in outby areas not related to or directly affected by the explosion. Based on enforcement action taken during previous inspections, the operator was subjected to a higher level of enforcement pursuant to section 104 (d) of the Federal Mine Safety & Health Act of 1977.



## EVENTS LEADING TO THE ACCIDENT

Development of the 2 North Mains was stopped in June of 2005 due to excessive water and adverse roof conditions. The 2nd Left Mains were subsequently mined until August of 2005 when adverse roof conditions and water inflow again caused development to stop. On September 28, 2005, the operator submitted a plan to bottom mine the 2nd Left Mains. The plan was approved on September 28, and bottom mining was started shortly thereafter. On October 3, 2005, the operator submitted a plan to extend bottom mining in the inby portions of 2 North Mains. The plan was approved on October 4, and bottom mining of the 2 North Mains was conducted. Upon completion of the bottom mining, the equipment was moved to the 2nd Left Parallel.

On October 12, the mine operator submitted a plan to MSHA to seal the 2 North Mains inby the 2nd Left Parallel. The mine operator also submitted a plan to use Omega Blocks to construct 40 inch thick Omega Block seals. On October 24, the mine operator's requests were approved. Seal construction began on October 24, 2005. By November 9, seven seals had been completed. The operator subsequently completed the next seal in the 63 Crosscut, No. 4 Belt between entry Nos. 2 and 3. The locations of the seals are shown in Figure 2.



**Figure 2 - Location of 2 North Main Seals**

Ventilation controls, including stoppings and overcasts, also had to be modified to accommodate the air change associated with sealing. By December 11, 2005,

the operator had completed the last two seals in the Nos. 1 and 9 entries, and made those ventilation changes.

On Friday, December 30, 2005, coal was produced. Miners did not produce coal on Saturday, December 31, 2005, but two shifts performed equipment maintenance, roof bolting, rock dusting, relocating equipment outby from the faces, and other duties. Miners did not produce coal on Sunday, January 1, 2006, but four miners worked the day shift, hauling and installing track ballast, performing maintenance on water pumps in 2nd Left Parallel section and at 46 Crosscut, No. 4 Belt and repairing the trolleyphone communication system. After performing maintenance on the pump in 2nd Left Parallel, they pumped the standing water in that area, and turned off the power to the pump. They repaired the trolleyphone communication system by resetting an electrical breaker located at 9 Crosscut, No. 4 Belt. According to the miners, the trolley system worked fine for the rest of the shift. After the completion of the day shift, the mine was idled.

Mine Examiners Fred Jamison and Terry Helms arrived at the mine around 2:15 a.m. on January 2, 2006, to conduct preshift examinations prior to the oncoming day shift. Dispatcher William Chisolm said he arrived about 3:30 a.m. to monitor communications and the AMS. Helms and Jamison indicated that they entered the mine at approximately 3:00 a.m., although Chisolm believed it was 4:00 a.m.<sup>1</sup>

Helms traveled into the mine by mantrip through the track entry. Jamison walked into the mine through the belt entry, and examined that entry to the 11 Crosscut, No. 1 Belt area where he walked into the track entry and met Helms. Jamison boarded the mantrip with Helms and they traveled to the No. 3 Belt drive. Jamison exited the mantrip at the No. 3 Belt drive and walked the belt entry to No. 4 Belt drive. Helms continued to the No. 4 Belt drive where he left the mantrip, traveling the No. 4 Belt to the mouth of the 1st Left Section and examined the 1st Left section. Jamison boarded the mantrip at No. 4 Belt drive and traveled the track entry to 2nd Left Parallel switch. He then examined the belt entry into the 2nd Left Parallel section. Jamison started his examination in the No. 1 entry at approximately 4:00 a.m. He determined the air quantity in the last open crosscut between the intake and return aircourses, which measured 11,241 cfm. Jamison continued across the section from left to right conducting his examination of the working places and the remainder of the section. He detected no methane during his examination of the section, which he completed at approximately 4:25 a.m. He examined the track entry to the 2nd Left Parallel

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<sup>1</sup> Jamison and Chisolm confirmed that they had a conversation prior to Jamison and Helms going underground, so their recollections regarding times may not be completely accurate, which they both acknowledged.

switch where he boarded the mantrip and traveled to 1st Left switch. He called the dispatcher and informed him that he would leave Helms' dinner bucket and coat at the 1st Left switch.

Jamison continued on the mantrip toward the mine opening. He stopped at a power center at 17 Crosscut, No. 3 Belt. He walked to the water pump in the return entry at 22 Crosscut, No. 3 Belt either before or after making an unsuccessful attempt to start the pump by resetting the breaker. Jamison boarded his mantrip and rode to No. 3 Belt drive. He exited the mantrip and examined the belt drive. Jamison walked to No. 2 Belt drive, examined it, and returned to No. 3 Belt drive. Jamison drove to No. 1 Belt drive. From there, he walked to No. 2 Belt drive and checked the pump across from No. 2 Belt drive. He then returned to No. 1 Belt drive, boarded the mantrip and proceeded to the surface, arriving at approximately 5:40 a.m.

While Helms and Jamison were conducting the preshift examination, other miners were arriving on the surface and preparing to start their 6:00 a.m. shift. Jamison exited the mine and told Pumper John N. Boni about the malfunctioning water pump at 22 Crosscut, No. 3 Belt. He also informed 2nd Left Parallel Section Foreman Martin Toler Jr. what he found during his preshift examination. Jamison entered his preshift examination results in the preshift examination record book, noting no hazards and no methane. Jamison walked back into the mine at approximately 6:00 a.m. and went to the No. 2 Belt drive to shovel coal spillage.

After Helms left the mantrip at No. 4 Belt drive, he walked to the 1st Left section and conducted a preshift examination between 4:20 and 4:50 a.m. Helms decided not to come out of the mine, so he called outside and told 1st Left Section Foreman Owen Jones what he found during his preshift examination. Owen Jones did not know Helms' location when he called. The preshift examination of the section revealed no methane, 14,510 cfm in the last open crosscut between the intake and return air courses and no hazards. Chisolm called Helms underground to inform him where Jamison had left his lunch bucket and coat. Chisolm did not know Helms' location when he spoke with him. Helms eventually proceeded to the 2nd Left Parallel switch area.

The 2nd Left Parallel section crew consisted of 12 miners: Thomas P. Anderson, Alva M. Bennett, James Bennett, Jerry Groves, George Hamner Jr., Jesse Jones, David Lewis, Randal McCloy Jr., Martin Toler, Jr., Fred Ware, Jackie Weaver, and Marshall Winans. They boarded a mantrip operated by Jesse Jones and entered the mine through the track entry at approximately 6:00 a.m.

Twelve miners were on the 1st Left section crew: Denver D. Anderson, Paul Avington, Gary B. Carpenter, Randall Helmick, Eric M. Hess, Owen Jones, Hoy

S. Keith, Jr., Arnett R. Perry, Gary Rowan, Harley J. Ryan, Christopher Tenney, and Anton R. Wamsley. The crew started to board a mantrip with John Boni, Belt Cleaner John P. (Pat) Boni, and Mine Examiner Ronald Grall. The crew realized that the mantrip they had was too small, and exchanged it for a larger one. The 15 miners boarded the mantrip operated by Owen Jones and entered the mine at approximately 6:05 a.m.

The 1st Left mantrip traveled to the 1 Right switch where John Boni exited the mantrip at approximately 6:14 a.m. He walked to the power center at 17 Crosscut, No. 3 Belt. John Boni moved the electrical plug from one receptacle to a receptacle protected by a larger breaker. He then walked to the pump at 22 Crosscut, No. 3 Belt in the return air course and confirmed it was operating. He started walking back toward the belt entry.

At approximately 6:19 a.m., Pat Boni exited the mantrip in the track entry near No. 4 Belt drive and walked to the belt drive. Pat Boni walked to 39 Crosscut, No. 3 Belt, refilled the trickle duster with rock dust and turned it on.

The mantrip stopped at the 1st Left switch. Perry exited the mantrip and threw the switch. He picked up a ladder near the switch and placed it on the mantrip.

## DESCRIPTION OF THE ACCIDENT

At approximately 6:26 a.m., Perry re-entered the mantrip at the 1st Left switch and was sitting down when a violent blast of air, smoke, dust and debris struck the mantrip and the miners. Owen Jones, the operator of the mantrip, tried to get into position to move the mantrip, but the force knocked him off of it, causing him to lose his hard hat. Owen Jones did not hear an explosion but estimated that the force lasted about 6 to 8 seconds. The other crewmembers' estimates ranged from 4 to 15 seconds. Owen Jones also stated that the dust in the air was so thick that he was unable to see, but that he did not smell any smoke at that time. Owen Jones' handheld detector alarmed, but he was unable to read the display showing the concentrations of methane, oxygen and CO in the air because of the dust. The force knocked off the hats, lights and glasses of some of the other 12 miners, and forced dust into some of their eyes and faces. The crew stated that they did not hear an explosion, or see any type of flash or flame.

The records of the AMS indicated that it alarmed at 6:31:31 a.m. but the clock in the AMS was four minutes and 56 seconds fast, so the time of the alarm was actually 6:26:35 a.m. At that time, the CO sensor at 57 Crosscut, No. 4 Belt alarmed, showing 51 parts per million (ppm). This was the first indication on the surface of something unusual occurring underground.

John Boni was in the No. 3 return entry at 22 Crosscut, No. 3 Belt next to the mandoor leading into the belt entry when he felt a rush of air. The power to the pump went off. Boni felt that the air was not very forceful, and was similar to a small pillar fall. He did not see any dust.

Pat Boni checked No. 4 Belt drive and started walking inby in the belt entry to check the belt take-up unit, when he felt a rush of air and dust from inby hitting him in the face. He grabbed his hat to keep from losing it, but estimated that the rush of air lasted only a second. The visibility after the rush of air was about 14 to 15 feet. His initial thought was that a roof fall had occurred nearby.

As Jamison was shoveling at the No. 2 Belt drive, he felt pressure in his ears. He thought there might have been a roof fall.

Once the rush of air subsided, the 1st Left crew began to exit the mantrip. Some of them felt heat. Rowan stated that the mantrip could not be used to evacuate the mine due to debris on the track. Rowan said that Perry shouted that the mine had blown up. Wamsley described the air as a yellowish brown. Owen Jones immediately instructed his crew to stay together and begin their evacuation outby on foot by walking in the track entry. However, the group did not stay together. Grall, Hess and Wamsley went ahead of the others working their way outby along the left rib of the track entry. Anderson stated that he thought two

or three people said the crew should put their SCSR on, but he did not remember who they were. Wamsley stated that he thought Owen Jones shouted to the crew to put their shirts over their mouths until they donned their SCSRs.

Visibility was very poor due to dust and smoke, with some miners describing it as no more than 8 to 10 inches. Hess stated that initially some miners tried to stay together by grabbing another miner's shirt, belt, belt loop or anything else they could. Their attempts to stay together were made even more difficult as they stumbled over debris from damaged ventilation controls.

Grall, Hess and Wamsley arrived at the first mandoor at 48 Crosscut, No. 4 Belt where they checked the No. 7 entry (the primary intake escapeway) and found the atmosphere to contain heat, dust and smoke, causing poor visibility. Hess and Wamsley decided that the situation was not good, and donned their SCSRs while in the No. 7 entry before going back to the track entry. Neither person had any difficulty donning their SCSR. Grall did not don his SCSR. He traveled back to the track entry and met Avington. Grall and Avington continued outby in the track entry looking for another mandoor, in an attempt to re-enter the primary intake escapeway. Somewhere between the mantrip and three to four crosscuts outby, Avington asked Grall if they should don their SCSRs. Grall said no, that they should just keep moving outby.

Hess and Wamsley re-entered the track entry through 48 Crosscut, No. 4 Belt. When they arrived in the track entry, they met Ryan and Anderson. Wamsley suggested that Ryan and Anderson don their SCSRs, and assisted Ryan with his. Ryan told investigators that he had difficulty grasping the tab to open the unit, and difficulty removing the bottom portion of the unit. They had to jerk the bottom of the unit two or three times to remove it. In addition, Ryan had difficulty breathing with the unit and, as a result of not having teeth, had difficulty keeping the mouthpiece in his mouth.

Hess assisted Anderson in donning his SCSR. Anderson stated that he had no trouble donning his SCSR. Hess said that he had trouble helping Anderson remove the SCSR from its pouch, since it had sealant on it, and because there was a pair of channel locks in the pouch. Once he removed the channel locks, Hess was able to pull the unit from the pouch, remove the metal straps from the top and bottom, and hand it to Anderson. Anderson was then able to complete the donning process and activate the unit. Anderson felt that his SCSR performed well, and the only problem was that the unit became warm.

Keith stated he was a little disoriented, and Wamsley assisted him in donning his SCSR. Wamsley stated that Keith's SCSR would not activate. He pulled the activation cord but it did not work. Keith thought the SCSR did function as intended, but that it did not make it easier to breath, because of the dust in his

mouth. Hess remembered Keith stating that his SCSR was not working the way it should.

Wamsley stated that when they re-entered the track entry he heard someone outby shouting to come his way. After donning their SCSRs, Ryan, Anderson and Keith continued outby in the track entry.

Helmick, Tenney and Carpenter stated that they did not don their SCSRs because they did not have trouble breathing, and thought that they may need them later. Owen Jones did not don his SCSR but acknowledged that he should have.

As Helmick, Tenney and Carpenter made their way outby in the track entry; they assisted other crew members who were having some difficulty walking. Tenney also noticed that air was hitting him in the face. This would indicate that the air was flowing from the outby to the inby direction, meaning that the air had reversed.

As Owen Jones made his way outby he came upon Perry, who had fallen down. Helmick arrived, and Owen Jones asked him to help Perry continue his evacuation. Helmick told Owen Jones that the other crew members were coming behind him, but he could not see them due to the thick dust. Perry said that he had lost his hat and the lens was broken on his cap lamp. During his evacuation in the track entry he decided to drop his damaged light so that he would have less weight to carry.

Grall and Avington continued outby ahead of the others, feeling their way along the dusty and debris-filled track entry, looking for another mandoor between the track and primary intake escapeway entry. Eventually they arrived at 37 Crosscut, No. 4 Belt where they entered the primary intake escapeway in the No. 7 entry. While there was still dust in the air there, the visibility was much better than in the track entry, with Grall reporting it being about 10 feet. Grall's detector was alarming, and the methane reading was one percent and falling. Grall did not state what the reading had been in the track entry. Grall continued to monitor his detector; with the last reading he recalled being 0.8%. He also recalled that the CO level at that time was 66 ppm and dropping. Avington remained in the intake while Grall returned to the track entry to check for the remaining crew members. The track entry was still dusty, and he could not see anyone. He shouted but did not receive an answer. He traveled outby to 30 Crosscut, No. 4 Belt and then returned inby to 38 Crosscut, No. 4 Belt without seeing anyone. He continued to shout in an attempt to make contact with the remaining crew members. He finally saw lights through the dusty atmosphere as the crew made their way in his direction. Grall estimated it took about another 5 minutes for everyone to reach the intake entry at 37 Crosscut, No. 4 Belt.

Ryan stated that once he reached the intake at 37 Crosscut, No. 4 Belt the “bottom part” of his SCSR air bag started to collapse. As he escorted Perry it became difficult to breath, and the unit was getting warm. Ryan felt that he needed more air than was being produced. Therefore, he would slow down when the unit would become warm. He said that the unit never actually stopped producing oxygen, and that the fresh air produced by the SCSR was better than the atmosphere in the mine.

After the rush of air, Jamison walked along No. 2 Belt toward No. 3 Belt drive to see if a stopping had been damaged. He did not find any damaged stoppings.

Pat Boni went to the mine phone located near the No. 4 Belt drive at approximately 6:32 a.m., called Chisolm on the surface and asked what had happened. Chisolm replied that lightning had knocked out some of the underground power. Pat Boni replied he did not think that was what had happened, since dust was moving inby rather than outby, the opposite direction in which air normally flowed. Chisolm confirmed after talking with Yardman Gary Marsh that the fan was still running. Pat Boni reiterated that the air was flowing inby, indicating something was wrong, and asked about the belts. Chisolm responded that Nos. 1, 2 and 3 Belts were operating, but Pat Boni could see that Nos. 3 and 4 Belts were not running, and he told Chisolm so. Pat Boni also said that the rock duster which he had started earlier was not operating, and the power center at No. 4 Belt drive was not energized.

John Boni went through the mandoor into the belt entry and continued to the track entry. There he saw a large amount of white dust that appeared to be rock dust. However, he did not see smoke, feel heat or hear anything. He noticed that the dust was just hanging in the air and not moving. John Boni immediately went to the mine phone at 1 Right switch to call Chisolm. He heard Pat Boni’s conversation with Chisolm. Pat Boni told John Boni what he observed at No. 4 Belt drive and that he thought there may have been a roof fall. Pat Boni said he would walk inby on the track entry to look for one.

Pat Boni stated he then went to the track entry and walked inby to the maintenance shanty, which he thought was at 8 Crosscut, No. 4 Belt.<sup>2</sup> He found it to still be dusty with the air still moving inby at 9 Crosscut, No. 4 Belt. He called the dispatcher from the phone at 9 Crosscut, No. 4 Belt to find out what happened. Chisolm responded that he did not know. Pat Boni told him that the air was going inby, and that he thought a fire or explosion had occurred.

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<sup>2</sup> The maintenance shanty was actually at 9 Crosscut, No. 4 Belt.



As the crew members were arriving at 37 Crosscut, No. 4 Belt and making their way into the No. 7 entry, Owen Jones stopped to use the mine phone near 37 Crosscut, No. 4 Belt in the track entry. He estimated that the call was made about 5 minutes after the explosion.

At approximately the same time the explosion occurred, Chisolm was speaking on the mine phone with Mine Superintendent Jeffrey Toler. Jeffrey Toler was in the building next to the dispatcher's office when a flash of lightning and loud thunder occurred. Chisolm heard a loud popping/ringing noise in the phone that caused pain in his ear, and made him drop the phone. After picking the phone back up, he told Jeffrey Toler that he had lost the AMS and that the belts were down. Jeffrey Toler could hear the AMS alarms over the mine phone. Jeffrey Toler told Chisolm to radio the 1st Left and 2nd Left Parallel Crews and ask them to check all the CO sensors which were alarming to determine the problem.

Chisolm also spoke on the phone to Wilfong, who was in his office, and told him that he had lost communications on the AMS. Wilfong thought that fuses must have blown, so he gave Maintenance Foreman Vernon Hofer, who was in his office at the time, a handful of fuses. He instructed Hofer to check the AMS and replace any blown fuses. Hofer proceeded to the dispatcher's office, checked in and obtained his cap lamp. He looked at the CO monitor screen to see which belts were affected and went to the pit to prepare to go underground. The Nos. 1 and 2 Belts were operating but the Nos. 3 and 4 Belts had lost power. The Nos. 5 and 6 Belts had not been operating when the explosion occurred.

Owen Jones called outside about "five minutes maybe" after they felt a rush of air. Owen Jones spoke over the mine phone to Chisolm, Jeffrey Toler and Wilfong on the surface, while John and Pat Boni listened in. Owen Jones said "I called out and I said, we've had a mine explosion in here. I said, get mine rescue team here now." He also indicated that there was a rush of air from the direction of 2nd Left Parallel, and that there was smoke. He was directing his men to the primary intake escapeway. After completing his phone conversation Owen Jones made his way to the No. 7 entry where he joined his crew members.

While at No. 3 Belt drive, Jamison overheard Owen Jones on the mine phone. Owen Jones was relaying his belief that there had been an explosion and that he was going to have his men evacuate the mine. Jamison decided to start walking toward the surface. While evacuating the mine he noticed that most of the mandooors along No. 1 Belt were open, and he shut them as he walked out. He did not indicate on which side of the track the doors were located. Jamison did not don his SCSR but said that he had it in his hand ready to don if needed.

Wilfong told Pat Boni over the phone to get in the intake and evacuate the mine. Pat Boni walked back to No. 4 Belt drive and picked up his lunch bucket and coat. He entered the primary intake escapeway through a mandoor across from the No. 4 Belt drive where the air was clear. Pat Boni walked the primary intake escapeway out to 4 Crosscut, No. 1 Belt. There he opened a mandoor between the intake and track entry. Seeing no smoke, he exited into the track entry and walked four crosscuts to the surface, arriving at about 7:25 a.m. During his evacuation, he did not see any other miners. Pat Boni did not don his SCSR. He felt that he was in good air since he did not see or smell smoke. When he arrived, there was no one in the pit area. Pat Boni immediately called the dispatcher from the phone in the pit to notify him that he was out of the mine.

John Boni asked Chisolm what the situation was, and he replied that there was a storm and that the power to No. 3 or No. 4 Belt had been lost, but that Nos. 1 and 2 Belts were still operating. John Boni stated that Wilfong and one of the other mechanics were on the phone, and that one of them said that they were coming in to reenergize No. 3 Belt.

John Boni told Chisolm to have them wait until he checked for a possible roof fall. He walked inby on the track entry about eight to ten crosscuts, but did not find a roof fall and returned to 1 Right switch. However, he did notice that dust was hanging in the air. John Boni called the surface again and spoke to Marsh. John Boni was thinking that there may have been an explosion and asked Marsh if there were any AMS sensors showing readings of CO. Marsh replied: "the ones on Two Left, the Two Left belt line, were showing CO. He told me what it was, 107 and 170 or something like that."

John Boni finished his conversation with Marsh when Owen Jones and Jeffrey Toler spoke on the phone. Jeffrey Toler asked John Boni where he was located. He then told John Boni to stay there so that he could pick him up. Owen Jones also informed John Boni that he was sending his crew out the primary intake escapeway and asked him to watch for them.

After the conversation with Owen Jones, Jeffrey Toler was concerned that the 2nd Left Parallel crew had not responded. He shouted to Safety Director James Schoonover, who was across the hall, to prepare to go underground. Jeffrey Toler, Schoonover and Wilfong then prepared to go underground. Wilfong called Hofer, who was in the pit area, and told him to wait so they could go underground together. Hofer moved a mantrip to the drift opening and waited.

As Jeffrey Toler, Schoonover and Wilfong were leaving for the pit area, Wilfong told Chisolm to continue trying to contact the 2nd Left Parallel crew. Once in the pit, Wilfong went to the main mine fan to check the fan pressure recording gauge. He told investigators that he noticed nothing unusual at that time, but

that later in the day he recognized a fine line on the recording chart indicating an instantaneous spike in pressure. Wilfong also later noticed that the chart had not been replaced after one revolution, and had run over, so he replaced the chart.

Wilfong, Jeffrey Toler, Schoonover and Hofer boarded the mantrip operated by Schoonover and proceeded underground. They did not take any gas detection instruments with them. No one could explain this oversight. Jeffrey Toler estimated that 10 to 15 minutes had elapsed from the time the explosion occurred until the time they started underground. The underground mine power system was not de-energized prior to them going underground.

While waiting for Jeffrey Toler, John Boni walked back and forth between the Nos. 6 and 7 entries watching for both the 1st Left crew to approach in the primary intake escapeway and for Jeffrey Toler to come in on a mantrip in the track entry. Realizing that there may have been an explosion, John Boni made a third call to either Chisolm or Marsh requesting that Jeffrey Toler bring in gas detectors, because he did not have one. However, Jeffrey Toler and the others had already started underground.

Once Ryan reached the intake entry at 37 Crosscut, No. 4 Belt he assisted Perry in donning his SCSR. Ryan stated that they did not have any trouble during the donning process. However, Ryan stated that Perry's SCSR air bag collapsed after walking about one crosscut (80 to 90 feet). He removed the mouthpiece and continued walking outby. Perry reported that the bag did not inflate at first. Perry also stated that he pulled the mouthpiece plug out, but did not pull on the activation cord on the bottom of the SCSR. Since Perry was short-winded and breathing hard, the breathing bag on his SCSR began collapsing. At that point, he exhaled into the bag to inflate it, but it was uncomfortable. He kept removing and reinserting the mouthpiece because he felt that he was not getting enough air. He also stated that the goggles were uncomfortable and were pushing on his eyes, so he turned them down away from his eyes.

Rowan stated that he did not don his SCSR until he reached the intake entry at 37 Crosscut, No. 4 Belt because they were in a panic, they were hoping to get to fresh air, and they needed to communicate with each other, which was difficult when wearing the unit. After reaching the intake at 37 Crosscut, No. 4 Belt it was still very dusty. Rowan decided to don his SCSR there. He did not experience any problems while donning the unit or while breathing with it. He acknowledged that he should have donned it immediately after the explosion occurred.

After Owen Jones' conversations with surface personnel, he walked to the intake entry where he joined his crew at 37 Crosscut, No. 4 Belt. Owen Jones instructed his crew members to immediately continue outby in the primary intake

escapeway. He stated that he was going to stay, but some of his crew pleaded with him to evacuate. He said that his brother, who was a miner on the 2nd Left Parallel crew, was inby and that he was going to see if he could do anything. Grall insisted that Owen Jones evacuate with them, saying he needed to think of himself, but Owen Jones refused. The crew members then proceeded outby without Owen Jones. Grall estimated that the crew was at 37 Crosscut, No. 4 Belt for about 2-3 minutes.

The crew made its way outby 37 Crosscut, No. 4 Belt in the No. 7 primary intake escapeway entry. Grall and Avington advanced ahead of the others and, when Grall looked back, he could no longer see anyone behind them.

As Rowan traveled outby, he assisted Keith, who was having difficulty breathing. It appeared that Keith's SCSR was working because the bag was inflated. On several occasions, Rowan removed the mouthpiece on his own SCSR and had Keith take a few breaths from it, in case Keith's was not functioning properly, but that did not seem to help.

Perry had lost his hardhat and had removed his cap lamp and battery earlier due to a broken cap lamp lens, so Ryan helped him as they made their way outby. Ryan would move ahead a crosscut and wait for Keith and the others who were helping him. Ryan would then move forward another crosscut and wait. Ryan stated that as the crew traveled outby, the visibility improved.

Hess stated that Avington and Tenney had handheld radios and made an unsuccessful attempt to contact the 2nd Left Parallel crew. Avington stated that he used his handheld radio while in the primary intake escapeway to tell Tenney to hasten their evacuation from the mine, and Tenney acknowledged him but was not sure what was said. Tenney stated that he had turned his handheld radio on while outside to check the battery, and then turned it off. He was planning to turn it back on when he arrived on the section, but never did. Tenney and Avington stated that they made no attempt to contact the 2nd Left Parallel crew.

Hess and Tenney stated that although the crew was spread out to some extent during their travel out of the mine through the primary intake escapeway, they did stay within sight of each other.

Once the crew members left to continue their evacuation from 37 Crosscut, No. 4 Belt, Owen Jones traveled back and forth from the primary intake escapeway to the track to check the conditions. The dust was starting to settle in the track

entry, but he could breathe better in the primary intake escapeway. Owen Jones' detector was alarming. He cleaned the display and discovered it was in the failure mode<sup>3</sup>, but he did not turn it off. Owen Jones decided to travel inby in the No. 7 entry in an attempt to find the 2nd Left Parallel crew. However, after traveling about half a crosscut, he thought about his detector alarming and realized he could be overcome by CO. He retreated to the phone in the track entry that he had used earlier. He said that the air smelled like oil or coal burning. His detector read 0.2% methane.

As the 1st Left crew was making their way out through the primary intake escapeway, Jeffrey Toler, Schoonover, Wilfong and Hofer entered the mine and traveled about two to three crosscuts, where they met Jamison, who was making his way out along the track entry. They asked if he was all right. When he replied that he was, Jeffrey Toler instructed him to continue to evacuate the mine.

Jeffrey Toler, Wilfong, Hofer, and Schoonover continued their travel into the mine until they arrived at 1 Right switch where they met John Boni. John Boni stated that he had been waiting for about 10 minutes, and had not seen the 1st Left crew. Jeffrey Toler asked John Boni for a detector but John Boni did not have one. John Boni boarded the mantrip and continued into the mine with the others. John Boni told Jeffrey Toler that he thought there was an explosion. Jeffrey Toler said that there could not have been an explosion, and questioned how it could have happened. John Boni responded that he did not know how, but that he thought it had occurred.

They continued into the mine and stopped near 25 Crosscut, No. 4 Belt. Wilfong used the phone to call the dispatcher at approximately 7:10 a.m. to see if he had heard from the 2nd Left Parallel crew. Chisolm responded that he had not heard from anyone. Owen Jones spoke to Wilfong and Chisolm on a phone near 37 Crosscut, No. 4 Belt. Wilfong thought that Owen Jones was attempting to make his way inby in an attempt to get to his brother. Wilfong told Owen Jones to get out of there before he was overcome by CO, and travel outby to their location.

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<sup>3</sup> Jones was probably carrying one of the following two types of detectors: Industrial Scientific Model LTX310 or Model ISC Model iTX. Neither of the two instruments will show the words "failure mode" on the display. The Model LTX310 instrument will show "BATTERY FAIL" on the display when the instrument has insufficient charge to operate. The Industrial Scientific Model ISC Model iTX instrument will show "FAIL" on the display. The instrument was examined by MSHA. The manufacturer was contacted and stated that the most likely reason for "FAIL" showing on the display would be that an attempt was made to calibrate the instrument in high concentrations of CO.

The 1st Left crew, with the exception of Grall and Avington who were some distance ahead, were continuing their way out through the primary intake escapeway, and came together at 27 Crosscut, No. 4 Belt. As the miners assembled at 27 Crosscut, No. 4 Belt they discussed using a scoop that was parked near their location to evacuate the mine. As they formulated their plans, they heard a mantrip in the track entry.

After Wilfong spoke to Chisolm on the surface, he returned to the mantrip and rode inby. Wamsley asked Ryan to go through the mandoor and flag down the mantrip. Ryan crawled halfway through the door at 27 Crosscut, No. 4 Belt and waved his light and shouted. Wilfong stopped and asked Ryan who was with him. Ryan responded that the whole crew was with him except for Avington and Grall. Ryan also indicated that Keith was not breathing well and had trouble walking, and that Perry had lost his hat and cap lamp and had trouble walking. Wilfong instructed Ryan to get everyone out to the track entry where there was fresh air, and said that he would take them outside.

Ryan then went back through the door and told the others that a mantrip was there, and that everyone should travel to the track entry. As the crew boarded the mantrip some of the crew members were relating to Wilfong, Jeffrey Toler, Schoonover, Hofer and John Boni what had happened, and that a stopping was out at 32 Crosscut, No. 4 Belt.

Grall said that when he and Avington reached 25 Crosscut, No. 4 Belt the air was clear, and they could see for a distance of about 500 to 600 feet. Grall and Avington continued their evacuation in the primary intake escapeway and approached 9 Crosscut, No. 4 Belt, where the maintenance shanty was located. There they heard a mantrip vehicle on the track entry, and traveled toward it. Grall noticed that the two large metal doors were open on the front of the maintenance shanty. He told Avington to check the track entry while he used the mine phone at that location.

During his travel into the mine, Wilfong had not observed any signs of an explosion. After seeing the condition of the 1st Left crew, and hearing their description of what they had experienced, Wilfong realized that the situation was more serious than he had first thought. As the crew continued to board the mantrip, Wilfong asked John Boni and the others to take a head count. Wilfong then ran back to the phone, and made another call to the surface and spoke with Chisolm, who at that time was talking with Assistant Director of Safety and Employee Development John B. Stemple, Jr. Wilfong told Chisolm to alert both the federal and state agencies, and stated that mine rescue teams were needed immediately.

As Wilfong was talking on the phone with Chisolm, Grall spoke on the phone, and informed Wilfong that he and Avington were at the maintenance shanty at 9 Crosscut, No. 4 Belt. Wilfong told Grall that the crew was boarding the mantrip near 24 or 25 Crosscut, No. 4 Belt and would be evacuating, and that they would pick him and Avington up. Grall first told Wilfong that he would walk, but that Avington preferred to ride, but then informed Wilfong that they would both wait for the ride. Grall estimated the time to be about 7:15 a.m.

Once Chisolm finished his conversation with Wilfong, he patched the land line phone into the mine phone, enabling Stemple to speak directly with Jeffrey Toler underground. It was approximately 7:15 a.m., and Jeffrey Toler advised Stemple that he was not sure what had happened. He said that they had found the 1st Left crew, and they were bringing them to the surface. Jeffrey Toler related that the 1st Left Crew stated that there were several intake stoppings out, and that there was smoke and dust in the air as they traveled along the primary intake escapeway. Stemple also learned from Jeffrey Toler that there had been no contact with the 2nd Left Parallel crew. He told Jeffrey Toler that he needed to re-establish ventilation as deep into the mine as he could in an attempt to prevent a short circuit of air to the 2nd Left Parallel section. Jeffrey Toler stated that he told Stemple to contact mine rescue teams.

Jeffrey Toler told Wilfong to take the 1st Left crew outside while he, Schoonover and Owen Jones remained underground. Wilfong then asked Schoonover and Jeffrey Toler to get Owen Jones, and to assess the damage and determine how far they could advance, while Wilfong, Hofer and John Boni were taking the 1st Left crew to the surface. He also then mentioned that the stopping at 32 Crosscut, No. 4 Belt just inby their location was out.

Hofer then operated the mantrip carrying the 1st Left Crew, John Boni and Wilfong toward the surface. They traveled outby to 9 Crosscut, No. 4 Belt where they picked up Grall and Avington. They continued toward the surface and arrived at the electric air lock doors along No. 1 Belt. Hofer asked Wilfong if they should switch from the electric doors to the manual doors. Wilfong said yes, and Hofer closed the manual doors but left the electric doors open. They continued out the track entry and arrived on the surface at approximately 7:30 a.m.

Owen Jones traveled outby to meet Jeffrey Toler and Schoonover at the mine phone at 25 Crosscut, No. 4 Belt. Jeffrey Toler noticed that Owen Jones did not have a hard hat, and instructed Owen Jones to stay at the phone while he and Schoonover traveled inby to assess the damage. As Jeffrey Toler and Schoonover traveled inby on the track entry, they noticed the first stopping damage at 32 Crosscut, No. 4 Belt where the stopping was blown out from the intake toward the track entry. They continued to travel inby to about 42 or 43 Crosscut, No. 4

Belt and noticed that other stoppings were blown out toward the track entry as well.

Jeffrey Toler and Schoonover decided to withdraw because they did not have any detectors with them, there was more than one stopping out and they did not know what conditions they would encounter. They traveled back to 41 Crosscut, No. 4 Belt where Jeffrey Toler stated a mine phone was located.

Jeffrey Toler called outside and spoke to Marsh. Jeffrey Toler told Marsh to have Wilfong and Hofer bring in curtain, nails, boards, saws, all available detectors and a hardhat for Owen Jones. Jeffrey Toler and Schoonover then walked back to where Owen Jones was, and waited for Wilfong and Hofer to return with supplies.

Marsh and miners Casey Short and George Brooks gathered the supplies, including two detectors, loaded them on a forklift, and took them into the pit area. Wilfong and Hofer arrived on the surface with the 1st Left crew. The 1st Left crew exited the mantrip and went to the bathhouse.

Hofer informed Brooks that the batteries on the mantrip were low, and instructed him to get a fully charged mantrip for their return trip into the mine. Brooks obtained another mantrip and Marsh, Brooks and Short began loading the supplies.

Wilfong told Hofer to stay in the pit while he went to the surface substation to de-energize the remaining power to the underground portion of the mine, including the AMS. Wilfong then signaled Hofer to pull the visual disconnect at the pit mouth, lock and tag out the underground mine power. Hofer then disengaged the knife blades on the pole in the pit and locked them out.

The AMS system was equipped with a battery backup that maintained power to the system when there was a loss of mine power. The system would remain energized until it was manually disconnected. That was not done at this time, and the AMS remained energized until discovered by mine rescue teams during exploration.

Hofer then went to the mine office and obtained handheld gas detectors and SCSRs. He returned to the pit area for the return trip underground with Wilfong.

From the substation, Wilfong went to his office where he encountered Perry, who had dirt and debris in his eyes. Wilfong provided brief assistance to Perry. From there, he obtained telephones, hammers and other materials and returned to the pit area to assist Marsh, Hofer, Short, and Brooks load the remaining



supplies ordered by Jeffrey Toler. Once the supplies were loaded and Hofer and Wilfong were prepared to enter the mine, Hofer mentioned that they would stop at the maintenance shanty at 9 Crosscut, No. 4 Belt to obtain additional hand tools.

Wilfong and Hofer entered the mine. Hofer turned one of the detectors on so that he could monitor the atmosphere as they traveled into the mine. The detector did not show any contaminants. They stopped at the maintenance shanty at 9 Crosscut, No. 4 Belt where Hofer obtained a sledgehammer, a slate bar and a pole axe. They proceeded inby and met Jeffrey Toler, Schoonover and Owen Jones. All five men went to 32 Crosscut, No. 4 Belt and installed a check curtain across the damaged stopping between the Nos. 6 and 7 entries on the intake side. Hofer stated that there was light air pressure toward the track entry. Hofer also stated that they noticed the return stoppings at 33 and 34 Crosscut, No. 4 Belt were damaged. They did not repair those controls. They boarded the mantrip and rode inby to 42 Crosscut, No. 4 Belt.

Hofer walked inby on the track entry. About half way between 42 and 43 Crosscut, No. 4 Belt he heard his detector alarming. He looked down at the detector and saw that the alarm light was also flashing. He retreated to 42 Crosscut, No. 4 Belt and moved to the intake entry. He checked the detector and it was showing 40 to 50 ppm CO. He also indicated that the CO was dropping on the detector at that time. The CO would have been higher in the track entry.

Jeffrey Toler's detector also alarmed, but he could not recall any readings. Concerned about causing another explosion, the men decided to de-energize the mantrip by disconnecting the batteries, and to leave it at 42 Crosscut, No. 4 Belt. At 42 Crosscut, No. 4 Belt, Schoonover noticed a small amount of dust and smoke moving in the outby direction in the track entry.

Wilfong gathered curtain, nails, spads, an axe and a detector and then proceeded into the intake entry. He installed a check curtain between the Nos. 6 and 7 entries at 42 Crosscut, No. 4 Belt.

They unloaded the remaining supplies at 42 Crosscut, No. 4 Belt. Jeffrey Toler, Schoonover, Wilfong, Hofer and Owen Jones then started to repair stoppings between the Nos. 6 and 7 entries as they moved inby. Some were damaged while others were not. They were not sure how many damaged stoppings they repaired as they moved inby on foot. Jeffrey Toler stated that the stoppings were blown out from the intake to the track entry, and the amount of damage ranged from partial to complete. During the investigation, it was determined that they installed check curtains at damaged or completely blown out stoppings at the following locations: 32, 42, 43, 45, 46, 47, 49, 54, 56 and 57 crosscuts along No. 4

Belt. They also installed a check curtain at the damaged overcast at 51 crosscut along No. 4 Belt.

Wilfong stated that they installed the check curtains starting from the outby end of the crosscut, working their way toward the inby end. This was done to remain in fresh air and force the CO inby and away from their work area. Wilfong noted that their detectors would alarm as they advanced, but as they installed a check curtain the air would clear and the alarms on the detectors would drop from high to low. They did not recall any actual readings. He also believed that the detectors would malfunction at times.

When the check curtains had been installed up to 49 Crosscut, No. 4 Belt, visibility improved and Hofer noticed more damage in that area. Jeffrey Toler asked Hofer where the closest phone was. Hofer responded that there was a phone in the track entry hanging from a roof bolt. Jeffrey Toler stated he wanted to have a phone in the fresh air, so he went to the track entry to obtain the phone. Jeffrey Toler stated that when he was in the track entry he observed in excess of 700 ppm CO on the detector he had with him. He did not want to cut the phone line in the track entry leading to the 2nd Left Parallel section, so he went to the 1st Left Belt drive at 49 Crosscut, No. 4 Belt and cut the phone line there. Jeffrey Toler then worked the phone line over to the No. 7 intake entry. Jeffrey Toler moved two Emergency Medical Technician boxes and a stretcher located in the crosscut between the track and intake entry to the No. 7 intake entry.

Crumrine stated that shortly after arriving at the mine he spoke on the mine pager phone to Jeffrey Toler who was underground. Crumrine recalled that Jeffrey Toler was either at 1st Left switch or near 42 or 43 Crosscut, No. 4 Belt. Jeffrey Toler told him that there had been an explosion or fire. He said that they did not have as much air volume or velocity as they should have. He said that there may be a stopping blown out behind him, meaning outby. He asked Crumrine to walk the intake entry into the mine and check ventilation as well as the ventilation into 2 Right. However, after completing the conversation with Jeffrey Toler, West Virginia Mine Inspector John Collins informed Crumrine that he was not permitted to enter the mine. It was between 8:15 a.m. and 8:30 a.m.

Hofer connected the phone line to the phone, and called outside to see if the phone was working. Marsh answered the phone and spoke to Hofer. Marsh told Hofer "I notified him at that time that we had a (k) order<sup>4</sup> and they were to evacuate the mines and not to proceed any further." Hofer stated that Marsh

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<sup>4</sup> The 103(k) order was issued verbally over the telephone by Satterfield to Stemple at 8:32 a.m. According to Stemple, Satterfield said "No one is to enter the mine or do any work at the mine from 8:32 on."

told him “he told me that there was a (k) order on the mines.” Hofer relayed the information to Owen Jones, who was standing beside him. Hofer asked Jeffrey Toler if he needed more curtain material. When Jeffrey Toler replied yes, Hofer went back to the mantrip at 42 Crosscut, No. 4 Belt to obtain more curtain material.

Jeffrey Toler stated that they placed a check curtain in 51 Crosscut, No. 4 Belt where an overcast over the track entry was damaged. The group continued inby in the No. 7 entry, installing check curtains at the damaged stoppings between the Nos. 6 and 7 entries.

At 42 Crosscut, No. 4 Belt, Hofer obtained a roll of curtain material, spads and nails and delivered the material to the area near 56 Crosscut, No. 4 Belt in the No. 7 entry where Jeffrey Toler, Schoonover, Wilfong and Owen Jones were waiting. He left the material there and returned through the intake entry back to 42 Crosscut, No. 4 Belt. He noticed that the visibility in the track entry was becoming poor due to smoke. He then began moving extra SCSRs, an extra detector, and two rolls of curtain into the No. 7 intake entry. One detector had apparently failed, so there was only one left. Wilfong stated that at some point Hofer had brought a couple of SCSRs to where Jeffrey Toler, Schoonover, Wilfong and Owen Jones were installing check curtains. However, they were not used.

As Jeffrey Toler and the others moved inby installing check curtains, they noticed that the air velocity was not as strong as it should have been. In the area between 55 to 57 Crosscuts, No. 4 Belt, Jeffrey Toler started thinking that they may have missed one or more damaged controls outby. Jeffrey Toler and Wilfong told Owen Jones to take a roll of curtain and go outby with Hofer in the primary intake escapeway to check ventilation controls between the primary intake escapeway and track entry, and to install curtain wherever there was a damaged stopping without a curtain.

Owen Jones proceeded to 42 Crosscut, No. 4 Belt where Hofer was moving the supplies from the mantrip area to the intake. Owen Jones and Hofer proceeded out the primary intake escapeway following the reflectors, and checked for any short circuit of air.

As Hofer and Owen Jones walked out the primary intake escapeway, Jeffrey Toler, Wilfong and Schoonover continue to install check curtains. After installing a curtain in 57 Crosscut, No. 4 Belt they advanced inby between 57 and 58 Crosscut, No. 4 Belt where they observed the conditions and listened. The smoke was extremely dense, hanging down about three feet from the roof and swirling. Visibility was very poor and getting worse. The smoke was too dense to permit them to hang a curtain in 58 Crosscut, No. 4 Belt. Jeffrey Toler wanted

to go inby. Wilfong told him they should not do that and that the best thing they could do was to go outside and report what the conditions were and where they had been. They could hear noises inby, which sounded like something falling. They repeatedly shouted in the general direction of the noise in an attempt to make contact with the 2nd Left Parallel crew, but did not receive a response. There is no testimony or other information to indicate that this group had with them or used any of the non-permissible handheld radios in an attempt to contact the 2nd Left Parallel crew.

Wilfong estimated that they waited about 15 to 20 minutes, and then discussed the situation. They believed that they had diverted all of the airflow toward the 2nd Left Parallel section, but thought that they should have more air at their location than they had. They thought a damaged stopping must have been missed. Wilfong stated that the three of them did not think that the 2 North Mains seals could have been blown out. Schoonover had taken some mine rescue training, and had some concerns. They decided that there was a potential of another explosion resulting from their actions, since they were forcing fresh air into areas where explosive gases might be present. Jeffrey Toler stated that the detector they had was still beeping, but he did not know what the readings were. Wilfong stated that the detector had reached its maximum reading and was in malfunction mode. Jeffrey Toler suggested that they should evacuate the mine and "let the professionals come in," because they are "trained in this." The others agreed.

Jeffrey Toler, Wilfong and Schoonover then started outby in the primary intake escapeway. When they arrived at 49 Crosscut, No. 4 Belt Jeffrey Toler called outside on the phone that was moved into the intake entry earlier and spoke with WVMHS&T mine inspector Collins. At approximately 9:30 a.m., he told Collins that they had made it to 58 Crosscut, No. 4 Belt, that their detectors were burned up and that they had run out of air, and that the soot and smoke were so bad that they could not go into the track entry.

When Owen Jones and Hofer arrived at 2 Right they found that the overcast over the No. 7 intake entry at 12 Crosscut, No. 4 Belt was damaged. Owen Jones stated that he noticed that a large amount of the intake air was short circuiting over the overcast to the main return. Owen Jones and Hofer picked up a piece of curtain material lying under concrete blocks from the damaged overcast, carried it to the overcast across the track entry and used it to install a check across the overcast over the track entry at 12 Crosscut, No. 4 Belt. This reduced the short circuit of air to the return entry at this location, thereby forcing more air inby.

Jeffrey Toler, Wilfong and Schoonover continued outby to 42 Crosscut, No. 4 Belt where the mantrip that Wilfong and Hofer had used on their return trip underground was parked. Wilfong stated that he thought that they might use

the mantrip to evacuate the mine, but when he looked through the check curtain that had been installed earlier and saw more smoke and dust there than when they had parked the mantrip, he decided that they should walk out the primary intake escapeway to the surface.

Jeffrey Toler had Wilfong and Schoonover travel the No. 9 entry, and Jeffrey Toler stayed in the No. 7 entry to check the stoppings. When they arrived around 12 Crosscut, No. 4 Belt at 2 Right, they saw Hofer and Owen Jones. Jeffrey Toler stated that he noticed some damage to a couple of overcasts in the 2 Right area. The walls of the overcasts were blown out. Owen Jones and Hofer told him they had already installed a check curtain on top of the overcast on the track entry at 12 Crosscut, No. 3 Belt.

Owen Jones stated that Wilfong told him and Hofer that they should get out of there, since all the fresh air was now flowing in by, which could force methane over any fire that might exist and cause another explosion. Jeffrey Toler, Wilfong, Schoonover, Hofer and Owen Jones then walked out of the mine in the primary intake escapeway and arrived on the surface at about 10:35 a.m.

At no time did Jeffrey Toler, Schoonover, Wilfong, Hofer or Owen Jones don an SCSR. Schoonover stated that no one donned an SCSR because he felt that there was no need to do so. Wilfong stated that he was saving his until he needed it.

### **The 2nd Left Parallel Miners**

Twelve miners were on the 2nd Left mantrip, which was operated by Jesse Jones. Thomas P. Anderson, Alva M. Bennett, James Bennett, Jerry Groves, George Hamner Jr., Jones, David Lewis, Randal McCloy Jr., Martin Toler Jr., Fred Ware, Jackie Weaver and Marshall Winans entered the mine through the track entry about 6:00 a.m.

Many of the following details concerning the events of the 2nd Left Parallel miners were obtained from physical evidence gathered during the investigation and from interviews of various mine rescue team members. Other details were provided by McCloy. He provided investigators with valuable information that only he would know. However, McCloy was still recovering from the effects of the accident at the time of his interview.

As the crew made their way to the 2nd Left Parallel section, McCloy did not recall speaking to or seeing Helms. The crew arrived on the section and exited the mantrip. The crew was walking toward the face when the explosion occurred. The initial effects of the explosion were noise, pressure, wind and a haze. McCloy stated he was not knocked over. There was pressure but his ears

did not pop. McCloy stated that Martin Toler took charge and gathered everyone together after the explosion.

McCloy indicated that no one tried to call out because all of the communication devices were damaged. He did not know if anyone tried to use the handheld radio communication system but he did not think it would have worked.

McCloy stated that they boarded the mantrip operated by Martin Toler and started outby on the track entry in an attempt to escape. During their travel outby, they encountered an atmosphere filled with smoke. They continued outby until the mantrip hit debris on the track at 10 Crosscut, No. 6 Belt. They exited the mantrip.<sup>5</sup>

A mine rescue team later indicated that the mantrip appeared to have encountered an Omega block that had been blown into the center of the track between the rails. The mantrip appeared to have come in contact with the block and moved it in the outby direction. As the block moved forward, the soot deposited on the gravel between the track rails was disturbed. It also appeared that the mantrip was then moved inby away from the block about two to three feet.

The crew donned their SCSRs, but McCloy could not remember exactly where or when. The top and bottom covers from twelve SCSRs were found at 11 Crosscut, No. 6 Belt in the No. 7 entry. According to McCloy, Martin Toler suggested that they don their SCSRs because they were in a small amount of smoke. McCloy stated that his SCSR worked fine, but that the SCSRs used by Groves, Anderson, Jesse Jones and Martin Toler did not work. McCloy indicated that he thought the other miners seemed to know how they worked, and indicated that they had been trained in their use numerous times.

McCloy indicated that when they discovered that the SCSRs did not work, there was some yelling and there was a lot of controversy. When asked how he knew that the SCSRs did not work he stated that it was a “no-brainer,” since the miners had been trained extensively. He also indicated that the crew had to remove the mouthpieces from their SCSRs in order to communicate.

At some point, Groves gave his SCSR to McCloy because Groves could not get it started. McCloy worked with the unit in an unsuccessful attempt to get the unit to work.

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<sup>5</sup> During their initial exploration, the mine rescue teams found the empty 2nd Left Parallel mantrip at 10 Crosscut.

McCloy stated the 2nd Left Parallel crew attempted to evacuate, and Martin Toler encouraged everyone to stay together. They tried several places to get out but everywhere they went it was smoky. However, McCloy said the visibility was never so poor that it was necessary to place their hands on each other or attach themselves in some manner like mine rescue teams.

A mine rescue team found footprints in the soot on the mine floor indicating that the 2nd Left Parallel crew traveled to 11 Crosscut, No. 6 Belt in the No. 7 entry where they apparently donned their SCSRs. The team continued to follow the footprints outby in the No. 7 entry a crosscut or two until they could no longer see the footprints.

Due to the smoke filled atmosphere limiting visibility, toxic gases, destroyed stoppings, and the debris on the track, the crew may have felt that all their options were exhausted, and there was no way out. They may have theorized that to try to travel on foot as a group in an attempt to escape would be extremely difficult.

Although all of the information that was available to the 2nd Left Parallel crew as they were considering their options is not known, it is possible to consider what information they may have had. They knew that the 1st Left crew had entered the mine after them. They knew that the mine had been idle the previous shift. They knew the mine was not very gassy. Although they knew the results of the preshift examination for the 2nd Left Parallel section, they may not have known the results for the preshift examination for the 1st Left section. History has indicated that most explosions are the results of the actions of men or machinery. Based on these considerations, it is possible they believed that an explosion occurred in the 1st Left section as the crew entered the section or just shortly thereafter. It would not have been likely that they would have considered an explosion originating from behind the sealed area. Although explosions had occurred in the past damaging seals, there was no history of an explosion of this magnitude or level of destruction. There was no obvious ignition source present, such as spontaneous combustion or an active fire. If they considered that the explosion had originated in the 1st Left section, then the conditions observed on the 2nd Left Parallel section would not be as destructive as what they may have expected to encounter in the mains as they attempted to escape. They may have considered the distance that they would have to travel and speculated that it would be impossible for them to accomplish it safely.

Martin Toler suggested that they go back to the section. Everyone agreed to go back to the section. As they traveled back toward the section in the belt line, they initially could not see very well.

They decided to build a barricade. McCloy recalled Martin Toler directing the installation of the barricade curtains. Toler, Anderson and McCloy assisted in the installation of the curtains. He thought that there could have been additional miners helping but could not recall who. They tried to make them “leak-free.” They decided to use curtain material from the face area since some of the crew indicated their SCSRs were not working. Although there was concrete block nearby, they felt that using block would take more work and “it would just not work.” McCloy recalled that visibility was good during installation of the curtains. He said that he removed his SCSR during the installation process.

Once behind the barricade it took several hours before the miners calmed down. They turned all their cap lamps off except for one, as Martin Toler suggested. There was conversation between them. The area they were in was large, and they would have to shout to each other at times.

McCloy indicated that the crew thought they would be rescued. They took turns using a sledgehammer to bang on a roof bolt. McCloy said that as each miner took his turn, he would take off his SCSR because he would get exhausted. McCloy said that this was the only time he removed his SCSR. McCloy thought that rescuers would bring the machine that locates people to the mine. According to McCloy, the crew thought that they would hear shots on the surface, rescuers would drill a hole in the right spot, and they would be taken out. They thought that they would be rescued, and discussed how long it would take. However, as time passed it did not look good. They were waiting for the borehole but felt that the rescuers must not have had the right equipment.

McCloy indicated that about an hour and a half after entering the barricade, Martin Toler and Anderson exited it. They walked to the power center across from the tailpiece. He thought that they did not have SCSRs with them. He believed that they were looking to see if the air was clearing and to see how far they could get. They made it to the power center but then returned. When they re-entered the barricade they were coughing and gagging, and were exhausted. McCloy said that Toler and Anderson said that there was too much smoke and that it was hard to breathe.

While in the barricade, McCloy removed his goggles. McCloy shared his SCSR with Groves while in the barricade. He was aggravated that Groves’ SCSR would not work, so he again made an unsuccessful attempt to get it to function. McCloy said that his and other miners’ SCSRs were depleted, but he could not recall whose.

During the time the miners spent in the barricade, some of them wrote personal notes to their family members. According to a note written by James Bennett at 11:40 a.m., they had air but the smoke was bad. At 2:45 p.m., Weaver wrote that



the fumes were getting terrible, but everyone was still partially ok. James Bennett wrote at 3:07 p.m. that the air was bad and that he did not know how much longer they could last. At 4:22 p.m., he wrote that time was running out and at 4:25 p.m., he wrote “we not heard anything from the outside.” The quality of the writing in each segment of the notes deteriorated with time.

McCloy did not see Martin Toler make any gas checks, did not hear any alarm from a gas detector, and did not think that Toler had a detector.

McCloy indicated that it was a long time before any of the miners went to sleep, or appeared to be sleeping. However, they did not all succumb at one time. McCloy did not know if all the others fell asleep before him because they were not all together. Some of his fellow miners were some distance away and it was difficult to see them.

## NOTIFICATION AND SAMPLING

Chisolm telephoned Stemple at home by 7:00 a.m., and patched him through to Wilfong, and then to Jeffrey Toler in the mine at 7:15 a.m. Around 7:20 a.m., Stemple contacted the General Manager of ICG's Buckhannon Division, Charles Dunbar, and told him that something had occurred at the mine but that he did not know exactly what. Stemple said he would call back once he got more information.

At approximately 7:30 a.m., ICG Purchasing Director Jerry Waters told ICG's Manager of Safety for West Virginia and Maryland, Harrison Tyrone (Ty) Coleman, that something had happened at the mine, and that Coleman should contact Stemple to obtain more details. Ty Coleman was Stemple's supervisor. Ty Coleman left home between 7:35 a.m. and 7:40 a.m. and drove to the mine. While driving, he called Stemple and told Stemple to activate the mine rescue teams and put them on standby. Stemple replied that he had already contacted them. Ty Coleman also contacted Dunbar, but Dunbar was already aware of the event and was either at the mine or on his way. Ty Coleman called ICG's Production Coordinator for the Buckhannon Division, Raymond Coleman, to inform him of the event at the mine. Ty Coleman estimated it took approximately 20 minutes to drive to the mine.

At approximately 7:45 a.m., Chisolm telephoned Crumrine to notify him of the events at the mine, but was unsuccessful and left a message. When Crumrine returned his call, Chisolm told Crumrine that there had been an explosion in the mine. Crumrine left his home and drove to the mine.

Stemple first attempted to contact personnel at the WVMHS&T Fairmont, West Virginia office around 7:40 a.m. He was unsuccessful, and left a message on the answering machine. At around 7:46 a.m., Stemple attempted to contact Collins at home. He was unsuccessful, and left a message on his answering machine. Shortly thereafter, Collins returned Stemple's phone call, learned of the event, notified his supervisors and drove to the mine.

Stemple called MSHA's Bridgeport, West Virginia Field Office Supervisor Kenneth Tenney at home around 7:50 a.m. He was unsuccessful, and left a message on his answering machine. Tenney was not at home and did not learn of the accident until later.

Dunbar and Crumrine arrived at the mine at approximately 8:00 a.m. Dunbar went to the dispatcher's office to talk to Chisolm. Crumrine went to his office and soon received a briefing from Chisolm. Crumrine assembled his mine gear and overheard Chisolm in a nearby office talking to Jeffrey Toler on the mine phone. Crumrine interrupted that conversation and talked to Toler. Jeffrey

Toler told Crumrine that they had some trouble in the mine and that an explosion, a fire, or something else had happened. Jeffrey Toler said that they did not have the quantity of air they should have, and asked Crumrine to walk the intake into the mine to check the ventilation system.

Ty Coleman arrived at the mine sometime after 8:00 a.m. and traveled to the superintendent's office to be briefed, and to be near a mine phone.

At 8:04 a.m., Stemple tried to contact Jeffery Rice, a member of the Barbour County Mine Rescue Team. Stemple then tried to contact personnel at the MSHA District 3 office in Morgantown, West Virginia at 8:05 a.m., but the office was closed due to the federal holiday. The telephone answering machine at the MSHA District office provided Stemple with a list of names and telephone numbers to contact in case of a mine accident or emergency. He proceeded to call them. Stemple unsuccessfully tried to reach MSHA District 3 Assistant District Managers Carlos Mosley and William Ponceroff, and District Manager Kevin Stricklin, and left messages on their cell phones concerning the accident. Stricklin's cell phone registered Stemple's message at 8:13 a.m.

Collins arrived at the mine at approximately 8:15 a.m. He was the first of many WVMHS&T representatives who would arrive at the site throughout the day. Collins went into the mine office and was briefed by Dunbar. Collins then saw Crumrine, who was exiting his office with the intent to enter the mine to check the ventilation system as Toler had instructed. Collins asked Crumrine to wait until more information could be obtained, and asked if anyone was monitoring the mine's return air.

At about 8:28 a.m., Stemple called MSHA's Bridgeport, West Virginia Field Office Supervisor James Satterfield and informed him of the events at the mine. After being briefed, Satterfield notified Stemple that he was issuing an order under section 103(k) of the Federal Mine Safety and Health Act. According to Stemple, Satterfield told him that nobody was to enter the mine or do any work at the mine after 8:32 a.m. Satterfield then attempted to notify MSHA District 3 Staff Assistant Ron Wyatt, and left a message about the accident.

At 8:30 a.m., Collins issued an order to the mine operator to preserve the scene of the accident. He explained the order and its requirements to Crumrine. Dunbar notified ICG's Senior Vice-President Sam Kitts that there may have been an explosion in the mine, and that 18 miners were unaccounted for. He also reported to Sam Kitts that the 1st Left crew had managed to get out, but that others had gone inside to investigate. Sam Kitts then telephoned and left a message for ICG President and CEO Ben Hatfield. Sam Kitts also called ICG Vice-President of Mining Services Gene Kitts, and asked him to notify other senior management officials at ICG.

At 8:35 a.m., Stemple contacted the mine, talked to someone whom he believed was either Chisolm or Marsh, and told him that he had notified the appropriate federal and state agencies. Stemple also notified him about MSHA's issuance of a 103(k) order. At some point Stemple also contacted the pastor of the Sago Baptist Church and obtained his permission to use the church as an assembly area for families, news media and mine rescue teams.

Stemple made contact with a mine rescue team at approximately 8:37 a.m. by speaking with Chris Height of the Barbour County Mine Rescue (BCMR) Team. Stemple asked Height to have the team assembled. The Barbour County team members assembled at their Volga, West Virginia station, prepared their equipment and headed for the mine at approximately 10:30 a.m. They were then to reassemble at the Sago Baptist Church across the road from the mine and wait for further instructions. As the day progressed, various mine rescue teams and personnel responded to the mine. A list of mine rescue personnel and teams responding is contained in Appendix C.

Around 8:40 a.m. Satterfield contacted Mosley on his cell phone and informed him of events at the mine. Satterfield informed Mosley that he had contacted MSHA inspectors Ron Postalwait and Argil P. Vanover and was meeting them at the Bridgeport field office to travel to the mine.

Collins asked contract Foreman James Scott and another foreman to monitor the mine's return air. At 8:40 a.m., Scott and the foreman acquired air quality and quantity measurements in the No. 1 Drift Opening. The air quality was 47 ppm CO, 0.0% methane and 20.4% oxygen. They determined the air quantity to be 93,204 cfm. At 9:10 a.m., Scott and WVMHS&T mine inspector Jeff Bennett obtained more air quality measurements in the No. 1 Drift Opening. Each took their own readings with their own instrument. Bennett's readings were 23 ppm CO, 0.0% methane, and 20.3% oxygen and Scott's instrument indicated 50 ppm CO, 0.0% methane, and 20.6% oxygen.

Around 8:43 a.m., Wyatt telephoned Satterfield concerning the message left earlier on his answering machine. Satterfield then briefed Wyatt on the events at the mine. Wyatt then contacted Ponceroff at his residence and informed him. At around 9:03 a.m., Wyatt contacted Stemple and obtained a briefing on the situation at the mine. During this conversation Wyatt asked Stemple if mine rescue teams had been contacted and Stemple informed him that they had been notified. At 9:05 a.m., Wyatt contacted Ponceroff and Mosley to provide them with an update on the situation. Ponceroff then asked Wyatt to meet him at the District office so they could then travel to the mine.

Gene Kitts telephoned ICG Corporate Director of Health and Safety Timothy Martin at home, told him the information he had about what had occurred at the

mine, and informed him that two crews were unaccounted for. At approximately 9:10 a.m., Martin contacted Bob Gardner, Vice-President and General Manager of Viper Coal in Williamsville, Illinois, to request that he activate the Viper mine rescue team. Martin then made several telephone calls to arrange transportation for the Viper mine rescue team from Illinois to the mine. He estimated that the team would arrive in Charleston at about 1:30 p.m. Prior to Sam Kitts leaving his residence at approximately 9:15 a.m., he received a call from Stemple informing him of the event at the mine. Sam Kitts informed Stemple that he had already been notified by Dunbar, and that he was on his way to the mine.

At about 10:00 a.m., WVMHS&T mine inspector Brian Mills contacted Joe Prevola of the Tri-State mine rescue team and asked that he have his team members respond to the mine accident. Prevola telephoned the team members and instructed them to gather at their office in Kingwood, West Virginia, to assemble their equipment. Once the team was gathered and assembled, they proceeded to the mine.

Shortly after 10:00 a.m., Mills contacted Spike Bane of CONSOL Energy, Inc. to inform CONSOL personnel of the accident at the mine and the potential need for CONSOL's mine rescue teams to assist in a mine rescue. Mills later had further telephone conversations with Bane on the events unfolding at the mine. Mills stated that he provided Bane's contact information to someone at ICG with instructions to contact Bane to get CONSOL's mine rescue team personnel on site.

Wyatt contacted MSHA Headquarters personnel to notify them of the accident at the mine around 10:00 a.m. Personnel there contacted the Chief, Mine Emergency Operations (MEO), Dr. Jeffrey Kravitz, about the accident around 10:15 a.m.; so that he could mobilize the agency's other resources, including MSHA's Mine Emergency Unit (MEU) members.

Shortly before 10:30 a.m., Satterfield and Vanover arrived at the mine and met with Jeffrey Toler. Postalwait arrived at the mine at about the same time. Satterfield instructed Postalwait and Vanover to monitor the pit area, including the return air exiting the No. 1 Drift Opening. Postalwait and Vanover made their first air quality measurement at 10:47 a.m., which indicated 500 ppm CO, 0.8% methane, and 19.8% oxygen.<sup>6</sup>

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<sup>6</sup> Air quality measurements were made using MSA Solaris multi-gas handheld detectors, which can detect a maximum carbon monoxide level of 500 ppm. At carbon monoxide concentrations exceeding 500 ppm, the Solaris instrument display screen will display 500 ppm.

Kravitz notified the Chiefs of the Ventilation and Physical and Toxic Agents Divisions of MSHA’s Technical Support about the mine accident between 10:45 and 10:50 a.m. They proceeded to notify their respective personnel in order to mobilize each Division’s available mine emergency capabilities. Those groups’ ability to respond was restricted since personnel and materials from both groups were at the West Elk Mine in Colorado. Most of their mine emergency equipment and manpower had been sent there to respond to a mine fire. In addition, some MEU equipment had also been deployed to the West Elk Mine.

Kravitz contacted Stricklin at 10:59 a.m. at his residence to request permission to use District 3 mine rescue personnel. This was how Stricklin first became aware of the accident. Stricklin made several telephone calls and traveled to the mine.

Bennett, Postalwait and Vanover made additional measurements of the return air exiting the No. 1 Drift Opening until about noon, the results of which are shown in Table 3.

Table 3 - Air Quality Measurements

Date	Time	Collector	Instrument	Carbon Monoxide (CO) (ppm)	Methane (CH <sub>4</sub> ) (%)	Oxygen (O <sub>2</sub> ) (%)
1-02-06	11:02 a.m.	Bennett	Explorer 4 <sup>7</sup>	472	1.0	19.0
1-02-06	11:02 a.m.	Vanover	Solaris	500	1.1	19.4
1-02-06	11:15 a.m.	Vanover	Solaris	500	1.1	19.4
1-02-06	11:28 a.m.	Bennett	Explorer 4	472	0.8	19.3
1-02-06	11:28 a.m.	Vanover	Solaris	500	0.9	19.7
1-02-06	11:30 a.m.	Vanover	Solaris	500	0.7	19.8
1-02-06	11:37 a.m.	Bennett	Explorer 4	472	0.7	19.5
1-02-06	11:37 a.m.	Vanover	Solaris	500	0.8	19.7
1-02-06	11:45 a.m.	Vanover	Solaris	500	0.7	19.8
1-02-06	12:00 p.m.	Vanover	Solaris	500	0.6	19.8

At about 11:30 a.m., Barbour County mine rescue team members assembled at the Sago Baptist Church to wait for further instructions. However, since the miners’ family members were using the church to wait for news, the team

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<sup>7</sup> Bennett’s air quality measurements were made using a CSE Corporation Explorer 4 handheld detector. The maximum CO which it is able to detect is 500 ppm. At CO concentrations exceeding 500 ppm, the Explorer 4 instrument display screen will display 500 ppm. However, if the CO sensor is weak or the instrument is out of calibration, a lower value may be displayed.

relocated to the mine. Team members set up their equipment at the mine and were ready to don their apparatuses by about 12:30 p.m.

Prior to Sam Kitts arriving at the mine, Hatfield telephoned him and received an update on the mine accident. Sam Kitts arrived at the mine site around 11:45 a.m., and met with mine management personnel to assess the situation.

At 12:00 p.m., Ponceroff and Wyatt arrived at the mine site. Mine management briefed them, and they traveled into the mine pit and met with Postalwait and Vanover, who were taking air quality measurements. Finding a CO reading of 500 ppm, Ponceroff and Wyatt decided to withdraw everyone from the pit area. Sampling in the No. 1 Drift Opening was conducted every 15 minutes and personnel entering the pit area continuously monitored the air quality. At 12:17 p.m., Bennett used an Industrial Scientific 270 Multi-gas detector to measure the air quality in the No. 1 Drift Opening. The measurement indicated CO in excess of 1,999 ppm.<sup>8</sup>

Martin arrived at the mine at approximately 12:15 p.m. and was briefed by mine personnel. He then assisted with ongoing activities until assuming the responsibility of ensuring that mine rescue teams were available and properly staged.

Carbon monoxide continued to be a concern, not only in the pit area, but in the surface buildings. At 12:20 p.m., Vanover issued an imminent danger order under section 107(a) of the Mine Act because of the extremely high CO levels detected in the No. 1 Drift Opening. The order required the withdrawal of all non-essential personnel from the pit and the surface buildings. Barbour County mine rescue team members were mobilized to conduct the sampling of the No. 1 Drift Opening.

At 12:30 p.m., Kravitz notified MSHA Mine Emergency Operations Group personnel to prepare the seismic system for possible deployment. Two technicians arrived in Pittsburgh, Pennsylvania at 2:45 p.m. to prepare the unit.

At 1:00 p.m., Sam Kitts went to the Sago Baptist Church and provided a briefing to the miners' families. At about the same time, elevated CO concentrations were measured outside and inside surface buildings. Those CO levels were 330 ppm and 130 ppm, respectively. MSHA personnel directed that all office and non-essential personnel leave the mine site. Shortly before the evacuation, Stemple arrived at the mine site. Stemple obtained a briefing from Crumrine and other

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<sup>8</sup> The Industrial Scientific 270 multi-gas handheld detector detects maximum carbon monoxide levels of 1999 ppm.

mine personnel and was informed that levels of CO were greater than 2,300 ppm in the pit mouth. Stemple noticed that Crumrine's handheld gas detector was in alarm, measuring 61 ppm CO. Stemple met with Ponceroff, Satterfield, and other MSHA and WVMHS&T officials, and assisted with evacuating non-essential personnel from the mine site, to either the Sago Baptist Church, or to the training room at the ICG cleaning plant located about a mile from the mine site. Around this time, Ty Coleman established the command center in Toler's office and started to assign personnel to set up the room for a command center, monitor the mine entrance, guard the mine site, and provide a workspace for engineering. Toler's office would serve as the command center for the rest of the rescue and recovery effort.

Shortly after 1:00 p.m., a formal plan was developed by the mine operator and approved by MSHA and WVMHS&T personnel to monitor mine gases in the pit mouth. The plan required two mine rescue team members to approach the mine entrances wearing full apparatus, and to monitor the gases exiting the mine. The plan required the results to be reported to the command center. The plan also required that two mine rescue team members wearing full apparatus stand at the edge of the pit to serve as backup to the personnel in the pit.

At 1:05 p.m., BCMR personnel started to take air quality measurements in the mine pit. Two rescue team members entered the pit and two watched from the top of the pit as emergency backup each time an air quality measurement was made. These measurements were made in Nos. 1- 4 Drift Openings. The results from the log are shown in Table 4.



**Table 4 - Air Quality Measurement by BCMR**

<b>Date</b>	<b>Time</b>	<b>Collector</b>	<b>Instrument<sup>9</sup></b>	<b>Drift No.</b>	<b>CO<sup>10</sup> (ppm)</b>	<b>CH<sub>4</sub> (%)</b>	<b>O<sub>2</sub> (%)</b>
1-02-06	1:05 p.m.	BCMR	iTX	1	+2000	0.0	20.9
1-02-06	1:07 p.m.	BCMR	iTX	2	+2000	0.0	20.7
1-02-06	1:09 p.m.	BCMR	iTX	3	4400	0.0	20.7
1-02-06	1:11 p.m.	BCMR	iTX	4	1700	0.0	20.7

BCMR personnel continued to obtain air quality measurements in the mine pit. BCMR air quality measurements taken between 1:25 p.m. on January 2 and 11:00 a.m. on January 3 are shown in Appendix D.

The Tri-State mine rescue team arrived at the mine site at approximately 1:30 p.m. At the same time, non-essential mine personnel were being allowed back on the mine site after being evacuated because of high CO levels. The CO levels in the mine office decreased. Tri-State member Chris Lilly noticed that some CONSOL teams were already on the property. The Command Center told Tri-State team members that CO levels measured at the No. 1 Drift Opening were too high for them to enter the mine. The WVMHS&T mine rescue trailer containing their mine rescue gear arrived.

CONSOL team members were arriving at the mine, and CONSOL sent safety department personnel to assist with coordinating and directing their teams' activities. CONSOL also sent a gas chromatograph and personnel to operate it to help in monitoring the mine's atmosphere for gases.

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<sup>9</sup> These air quality measurements were made using an Industrial Scientific iTX multi-gas handheld detector. The iTX can be equipped with either of 2 types of CO sensors. The 4 series sensor has a range of 0 - 999 ppm CO. The maximum indicated concentration on the instrument display is 999 ppm CO. The display indicates "OR" if the maximum range is exceeded. This is the standard sensor. The 7 series sensor, used at Sago, has a range of 0 - 9,999 ppm CO. The maximum indicated concentration on the instrument display is 9,999 ppm CO. The display indicates "OR" if the maximum range is exceeded.

<sup>10</sup> BCMR air quality measurements were documented by MSHA. The 1:05 p.m., 1:07 p.m., 1:09 p.m. and 1:11 p.m. Carbon Monoxide measurements were found to be inaccurate after they were entered into the log. The CO peak readings stored in the iTX multi-gas handheld detector memory were checked, and actually indicated a maximum CO value of 1,386 ppm, not the CO values of +2,000 ppm, +2,000 ppm and 4,400 and 1,700 ppm documented in the log. The log was not corrected. Also, the maximum CO value for the sensor installed in this instrument might have been exceeded. Following this series of readings, MSHA personnel provided training to BCMR personnel on use of the iTX multi-gas handheld detector.

Stricklin arrived at the mine site between 1:45 p.m. and 2:00 p.m. He obtained a briefing from Ponceroff, Wyatt and Satterfield on the status of the missing miners, the miners who had escaped, mine management's rescue attempt and the condition of the mine.

Personnel from MSHA's Ventilation and Physical and Toxic Agents Divisions organized and readied for transport a set of infrared and electrochemical gas analyzers, several thousand feet of 3/8 inch PVC tubing, vacuum pumps, four handheld permissible radios, a gas chromatograph, and the associated computers needed to operate the gas chromatograph and analyze the gas results. They left Pittsburgh, Pennsylvania with this equipment at around 2:00 p.m.

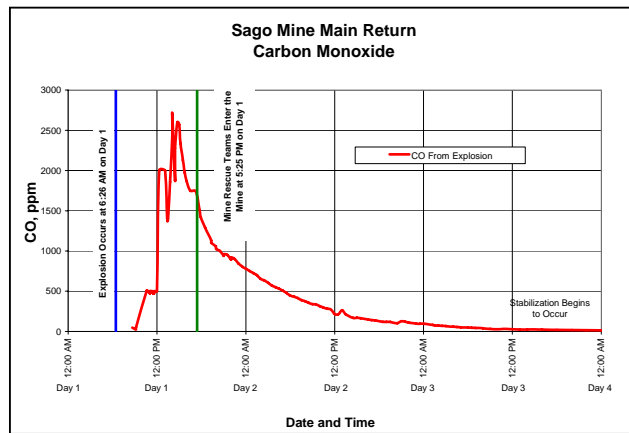
CONSOL's gas chromatograph was placed in the WVMHS&T's mine rescue trailer and readied for operation. CONSOL technicians calibrated the instrument and had it operational by 3:00 p.m. to analyze air samples collected in the mine drift openings. The gas chromatograph provided the capability to monitor additional gases and allowed a means to verify the readings for the CO, methane and oxygen being obtained from the handheld instruments.

The Viper mine rescue team arrived at the Charleston, West Virginia airport around 1:40 p.m. and was escorted to the mine by West Virginia state police, arriving around 3:30 p.m. At about this time, personnel designated by the Command Center briefed the mine rescue team captains concerning the accident.

At about 3:30 p.m., construction of a road to provide access to the 2nd Left Parallel borehole drill site was begun. The construction and site preparation took about 3 hours to complete.

Air quality measurements from the drift openings indicated a downward trend in the levels of dangerous gases. It was after 4:00 p.m. when the mine operator submitted requests to send mine rescue personnel into the mine. However, MSHA and WVMHS&T denied these requests because the levels of CO exiting the mine were still too high, reflecting a substantial risk of fire and the possibility of another explosion. The mine rescue teams were briefed at 4:15 p.m.

The air quality readings continued trending downward. Figure 3 illustrates the results of CO measurements obtained in the No. 1 Drift Opening. While they were still at dangerous levels, it was determined that they were low enough to allow rescue efforts to commence. At 4:55 p.m., the mine operator submitted a plan for the start of exploration which was approved by MSHA and WVMHS&T. The plan called for Tri-State Team A to enter the No. 5 intake entry and to explore the first 1,000 feet. Tri-State Team B would serve as their backup in the event Team A personnel experienced any type of difficulty. At 5:12 p.m., the mine operator submitted a new plan switching the Tri-State teams to the CONSOL teams, since CONSOL's teams had more experience in mine rescue than any other team present.



**Figure 3 - CO Measurements at the No. 1 Drift Opening**

MSHA's Ventilation and Physical and Toxic Agents personnel arrived at the mine site at approximately 5:15 p.m. and were briefed by Stricklin. They began to set up atmospheric sampling equipment, consisting of infrared and electrochemical instantaneous monitoring equipment, a gas chromatograph, and all associated equipment. During the set up process, electrical power had to be provided. A sampling line had to be extended to the No. 1 Drift Opening since a previously installed line was plugged. Four handheld permissible radios were distributed to MSHA's MEU personnel. At 5:25 p.m., the CONSOL Robinson Run A mine rescue team entered the mine through the fan house and proceeded inby exploring the mine.

## RESCUE AND RECOVERY OPERATIONS

### **Mine Rescue Protocol**

A basic mine rescue protocol has evolved over the years based on rescue efforts made during previous mine disasters. However, each mine disaster is unique, presenting a number of situations requiring difficult decisions. Most operations begin with establishment of a command center, which is headed by the mine operator. State and federal officials and sometimes miners' representatives are generally part of the command center. MSHA issues a section 103(k) order which requires a written plan to be proposed by the mine operator. It must be approved by MSHA and agreed to by the parties in the command center before it can be implemented. All of the decisions concerning the rescue operation, including mine rescue team movement, the areas of exploration and all related work are made in this manner. All teams are briefed before entering the mine and debriefed upon exiting.

A mine rescue team establishes a fresh air base (FAB) which includes a hard-wired communications system running to the surface command center. The FAB is the communication hub between the exploring teams and the command center. Exploration begins with one rescue team generally composed of five members. Each member is equipped with a breathing apparatus weighing approximately thirty-five pounds and consisting of a full-face mask and a supply of oxygen. A back up team is stationed at the FAB. They are ready to assist the exploring team if needed. A third team is on the surface, ready to provide support to the teams underground. Communication from the exploring team to the FAB is made by handheld permissible radios or by using a hard-wired communication system connected directly to the FAB. Rescue teams can typically explore about 1,000 feet from the FAB. After an area has been explored, ventilated and made safe for travel, the FAB is advanced. This continues until the operation is completed.

It is critical that ventilation not be changed in an area that has not been explored. This may allow explosive gases to come in contact with an ignition source, such as a fire, causing a subsequent explosion. If ventilation has been severely disrupted such that it is no longer possible to establish a FAB that is in fresh air, it may become necessary for the mine rescue team to begin to airlock as they advance. The mine rescue team builds temporary ventilation controls across all entries just in by the existing FAB. They then completely explore the next 1,000 feet in each entry. They build another set of temporary ventilation controls at that location. They repair ventilation controls between the two sets of airlocks. They remove the first set of airlocks and re-ventilate the area, relocate the FAB and start the process again. Airlocking efforts are labor and time intensive.

MSHA deploys MEU personnel to mine disasters. The purpose of the MEU is to provide technical and expert assistance during emergency operations. MEU members have extensive experience in mine rescue and recovery operations throughout the nation. MEU is self-supported and provides an assortment of specialized equipment such as permissible radios and handheld air quality detectors. During any mine related exploration, MEU personnel are assigned to the exploration team and to the back-up teams. Their presence has proven invaluable to mine rescue operations.

### **Mine Gases**

Methane and coal dust explosions have occurred in underground coal mines. These explosions can develop overpressures of 20 psi or more. MSHA investigated numerous methane and/or dust explosions and, with 2 possible exceptions,<sup>11</sup> had not observed evidence of explosion overpressures exceeding 20 psi. The pressures generated by an explosion are well in excess of the 2 to 4 psi that ventilation controls, such as stoppings, are able to withstand. Investigators have found that damage to ventilation controls after an explosion is quite common. This damage usually causes a short circuit in the ventilation system which may allow methane to accumulate.

The ignition temperatures of coal, wood, and other combustible materials found in a coal mine are less than the temperature of the explosion flame. However, the speed of the flame from an explosion can propagate in excess of 1,000 feet per second.<sup>12</sup> At this speed, the explosion flame contacts each point in the explosion zone for only a brief period of time, typically less than 100 milliseconds. This

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<sup>11</sup> An explosion occurred in the Production Shaft of Consolidation Coal Company's Blacksville No. 1 Mine on March 19, 1992. A cap was placed on the Production Shaft. An explosive methane/air mixture began to accumulate in the shaft. It was ignited by arc welding operations occurring on top of the cap. The subsequent explosion generated overpressures at the top of the shaft of approximately 1000 psig. The unusual circumstances resulted in a detonation of the fuel.

An explosion occurred in a sealed area of U.S. Steel Mining Company's Oak Grove Mine on July 9, 1997. Although a lightning strike of +145,200 amperes was determined to be the cause of the ignition, the path of that lightning strike into the sealed area was not defined. The sealed area had a total of 38 seals. Access into the sealed area after the explosion was not possible. Seven cementitious seals may have been damaged by the forces. Four seals had minor damage which may have affected their strength. Three seals were partially or completely displaced. The compressive strength of two of these three seals were found to be below the minimum acceptable limit of 200 psi. The information that the third seal had a compressive strength in excess of 200 psi led the investigators to indicate that the explosions forces required to damage the seal was in excess of 20 psi. Subsequent opinions by MSHA determined that the number of samples subjected to compressive strength testing was inadequate to fully support this conclusion.

<sup>12</sup> The Explosion Hazard in Mining, U.S. Department of Labor, Mine Safety and Health Administration, Informational Report 1119 (1981), John Nagy, Page 61.

length of time is generally too short to directly involve all these materials in a massive fire. The flame of the explosion also includes suspended coal dust that is heated to above the ignition temperature of various combustible materials. As the flame of the explosion slows and terminates, this coal dust drops out of suspension and accumulates on available surfaces. These surfaces may be the mine entry, crib blocks, roof support posts, or other combustible materials. It is possible that materials with a low ignition temperature may begin to smolder and eventually ignite under these conditions.

When an explosion occurs, large volumes of toxic and flammable gases are produced due to the incomplete combustion of these fuels. These gases include carbon monoxide, carbon dioxide, hydrogen, acetylene, and ethylene. The concentration of these gases can vary depending on the concentration of the fuel involved in the explosion. For example, in a coal dust explosion, CO concentrations can be 1,000 ppm when the initial coal dust concentration is 0.1 ounce per cubic feet.<sup>13</sup> The data also indicated that if coal dust was the sole fuel source involved in the explosion at a concentration of one ounce per cubic foot, CO could be formed to as high as 46,000 ppm.<sup>14</sup> In the case of methane explosions, post-explosion CO concentrations are approximately 500 ppm when a 9% methane/air mixture is ignited. CO levels can reach 80,000 ppm when the initial concentration of ignited methane increases to 12%.<sup>15</sup> Other gases are produced during explosions which are asphyxiates. These gases may not be toxic or flammable but can displace the oxygen necessary to sustain life.

When fires first begin, they produce barely detectable levels of CO. As the fire begins to grow and intensify, the level of CO production also begins to grow. The rate of growth of the fire depends on a number of factors, including the fuel and the amount of available oxygen. Carbon monoxide levels can reach well in excess of 10,000 ppm during a fire.<sup>16</sup> The temperature of the flame of a fire exceeds 1,500 degrees F. The ignition temperature of methane is 1,000 degrees F.<sup>17</sup>

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13 The Explosion Hazard in Mining, U.S. Department of Labor, Mine Safety and Health Administration, Informational Report 1119 (1981), John Nagy, Page 63.

14 Id.

15 Id.

16 Mine Fires Prevention, Detection, Fighting, Donald W. Mitchell, P.E., (1996), 3d Ed., pp 69-70.

17 The Explosion Hazard in Mining, U.S. Department of Labor, Mine Safety and Health Administration, Informational Report 1119 (1981), John Nagy, Page 52.

The most important consideration after an explosion is the safety of the mine rescue persons and that of any missing miners. Before sending any person, including mine rescue teams underground, the atmosphere in the mine must be assessed. The atmosphere should be monitored as close to the area of the explosion as possible. This can be accomplished with a borehole. However, a borehole is generally not present and it may take a considerable amount of time for one to be drilled. The only monitoring location available may be where the return air exits the mine. The air at the monitoring location may be diluted and may not give an accurate representation of the conditions in the area of the mine where the explosion occurred.

Monitoring of the mine atmosphere should begin as soon as possible. After a mine fire or explosion, the mine atmosphere can be monitored with handheld instruments, infra-red equipment, or gas chromatographs. The handheld instruments are the most readily available and are usually the first equipment on site. They can detect methane, CO, and oxygen. The detection levels vary for each instrument. Generally, the detection level for methane is 0 to 5%. The detection level for CO varies but generally ranges from 0 to 500 ppm for some instruments or from 0 to 999 ppm for others. It is important to know and understand the detection levels of the instrument being used. Infra-red equipment is generally used to measure methane in ranges from 0 to 100%, CO in ranges from 100 to 20,000 ppm, and carbon dioxide in ranges from 0 to 4.0%. Gas chromatographs are generally not very portable but are highly accurate and able to monitor most ranges of gases including methane, oxygen, carbon monoxide, carbon dioxide, and fire gases such as hydrogen, ethylene, and acetylene. Determining trends of the mine gases may be accomplished with any of the described detection equipment, but the gas chromatograph is generally used for this purpose as it is the most accurate.

It is also important to determine what the fuel was for the explosion. This information is very difficult to determine initially. Again, since a borehole in the area where the explosion is thought to have occurred is generally not available, monitoring of the return air where it exits the mine may be the only available option. Coal mines liberate methane. It is important to know the normal concentration of methane and the air volume in the monitored air. If it is different than normal, the cause for the difference must be determined before allowing personnel to proceed underground. For example, if the concentration of methane is lower than normal and the volume of air is the same, this may indicate a major short circuit in the ventilation system and methane may be accumulating in the area where the explosion occurred. This is also the area where a fire is most likely to be occurring. If the methane concentration is higher than normal and the volume of air is the same, this may indicate that there was an accumulation of methane somewhere in the mine that was not consumed by

the explosion. This could indicate an accumulation of methane is still in existence in the mine.

Unfortunately, there is recent history of fires starting after explosions. Most recently:

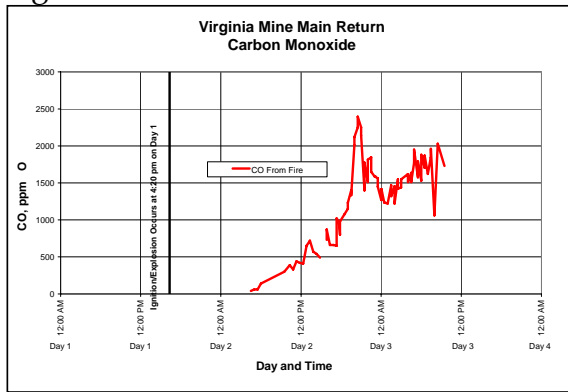
- An ignition/explosion occurred at a mine in Virginia and the miners were evacuated. The air exiting the mine was continually monitored for CO and other fire gases. Before the CO trend had stabilized, it began to trend upward and the mine was subsequently sealed at the surface. When the mine was reopened, evidence of two separate fires was discovered. One was relatively close to the reported location of the ignition/explosion origin. Evidence of a second fire was found thousands of feet away.
- A fire occurred after a series of explosions occurred in a mine in Alabama. Although mine rescue teams re-entered the mine, they were subsequently withdrawn after elevated concentrations of methane and a fire was discovered. The area was subsequently sealed.
- An explosion occurred at a mine in Illinois. It appeared to have originated in by the longwall face. After the atmosphere in the mine went through a stabilization period, mine rescue teams were permitted in the mine. During their exploration, they found a crib block still burning only a few feet away from an accumulation of explosive methane.

The forces of the explosion disrupted the mine ventilation system. It took a period of time for the CO generated from the explosion to reach the main return, No. 1 Drift Opening. As previously shown in Figure 3, the CO began to increase dramatically, peaked and then began to decrease. The CO trend eventually stabilized.

Persons generally should not re-enter a mine until the atmosphere has stabilized. The generally recognized stabilization time period is 72 hours. This minimizes the risk to persons from a secondary explosion.



Figure 4 illustrates the results of CO measurements obtained in one of several return shafts in a mine in Virginia after an ignition/explosion and subsequent fire. The ignition/explosion occurred in the mine at 4:20 p.m. on Day 1.



Although there were no samples collected immediately after the ignition/explosion, the gases from the event reported to multiple return shafts.

**Figure 4 - CO Measurements from a Mine in Virginia**

It took time for the fire to become large enough to be readily detected at a return shaft but eventually began to increase dramatically. The mine was subsequently sealed at the surface because of the increasing trends.

It can be seen how CO being produced from a developing fire could be masked by the CO that had been produced by an explosion. If a fire would have started in the Sago Mine after the explosion, as it did in this Virginia mine, it would have taken a significant period of time until the CO produced from the fire exceeded the CO produced from the explosion.

At the Sago Mine, a borehole into the area where the explosion occurred was not initially available. Monitoring of the main return was initiated with handheld instruments after the explosion occurred. The initial information indicated the volume of air exiting the mine had not changed significantly. It also indicated relative low CO and methane levels. About 10:30 a.m., the CO levels exceeded the detection limits of the handheld equipment and the methane levels were greatly in excess of the normal levels. The levels of CO remained above the detection level for handheld equipment. A gas chromatograph became available at about 3:00 p.m. Gas chromatograph analysis results for No. 1 Drift Opening are shown in Appendix E. The mine air analysis from the gas chromatograph confirmed the elevated CO and methane levels. These levels continued in a downward trend throughout the afternoon. The CO and methane levels were still trending downward but had not yet stabilized. It was not possible to know with any certainty if the explosion had started a fire in the mine. The elevated methane levels confirmed the possibility of methane accumulations in the inby areas of the mine. Even though these conditions existed, at 4:55 p.m., the command center made the decision to permit the mine rescue teams to begin to explore underground. There was a high degree of risk associated with this decision and it was discussed with all parties including the mine rescue teams before they started underground.

## Mine Exploration

At 5:15 p.m., the CO at the No. 1 Drift Opening was still dangerously high at 1,740 ppm, but the downward trend had been continuing for several hours. At 5:25 p.m., the CONSOL Robinson Run A mine rescue team entered the mine through the fan house and proceeded inby exploring the mine. The CONSOL Blacksville No. 2 mine rescue team was assigned as their backup team. By 5:57 p.m., exploration had reached 9 Crosscut, No. 3 Belt. Exploration then paused to allow team members to check air quality, air quantity and water depths in the explored area.

By 7:20 p.m., MSHA's instantaneous sampling equipment was set-up and monitoring the mine atmosphere exiting No. 1 Drift Opening. Initial readings indicated 1,200 ppm CO, 0.2% methane, and 20.6% oxygen. Gas measurements were recorded about every 15 minutes during the rescue operation. A trend analysis of these measurements was maintained.

The mine operator raised a concern about the need to start dewatering the return entries at the inby end of No. 1 Belt to prevent water from blocking the return air course. To address this issue, the mine operator submitted a plan, which was approved by MSHA and the WVMHS&T. This plan permitted the mine rescue team to energize power to a 150 kilovolt-ampere (kva) transformer, located at 23 Crosscut, No. 1 Belt, to power a dewatering pump located in the adjacent return entries. The water pump was energized at approximately 7:55 p.m.

At about 8:05 p.m., rescue teams continued their search. The rescue teams continued pushing into the mine until 2:13 a.m. on January 3, when they reached 32 Crosscut, No. 4 Belt. The team saw a red light glowing at approximately 36 Crosscut, No. 4 Belt in the belt entry. Rescue team members identified the light as coming from the AMS system, and believed the system to be energized by electrical power. Due to the risk of an explosion which such an energized component could cause, team members were ordered to retreat out of the mine at 2:40 a.m.

The command center ordered the rescue teams to maintain their positions out of the mine until the AMS power was de-energized, which was completed at 3:57 a.m. The teams were then to re-enter the mine. However, an effort to drill a borehole into the mine was occurring at the same time as the rescue effort. Personnel at the drill site notified the command center that the borehole into the 2nd Left Parallel section would be completed in about one hour. At that time, all mine rescue personnel would need to be withdrawn from the mine due to the explosion hazard which drilling through the roof could create. The command center ordered the rescue teams to hold their positions until the borehole was completed. The 2nd Left Parallel borehole penetrated the mine at 5:35 a.m. at a

depth of 258 feet. The borehole intersected the section at 23 Crosscut, No. 6 Belt in the No. 4 entry. An air quality sample taken from the borehole at 5:53 a.m. indicated 1,052 ppm CO and 20.4% oxygen. The drillers tapped on the drill steel and listened, hoping to hear a response from the trapped miners. No response was heard.

Rescue teams re-entered the mine at approximately 6:57 a.m. In addition, MSHA's robot was transported into the mine with the teams to 27 Crosscut, No. 4 Belt. The robot was to be used as an additional rescue tool to travel the track entry into 2nd Left Parallel. The rescue teams arrived at 27 Crosscut, No. 4 Belt at approximately 7:34 a.m. Team members unloaded the robot and sent it inby toward 2nd Left Parallel. The teams then began to explore inby 27 Crosscut, No. 4 Belt, independent of the robot. At about 8:48 a.m., the robot became disabled at 32 Crosscut, No. 4 Belt.

At 10:45 a.m., as teams continued to explore, the mine operator submitted a plan to have the teams explore to 48 Crosscut, No. 4 Belt, then proceed to explore the return entries of 1st Left for a distance of six crosscuts. Teams were also to examine the overcasts at 49 Crosscut and 51 Crosscut, No. 4 Belt. Once these examinations were completed, exploration was to proceed inby toward the 2nd Left Parallel section by exploring and using the Nos. 7, 8 and 9 intake entries until reaching and examining the seals inby 62 Crosscut, No. 4 Belt. Once the seals were examined, exploration was to continue toward the 2nd Left Parallel section. The plan was approved and the mine rescue teams continued their exploration. At 2:13 p.m., they found the 1st Left crew's abandoned mantrip between 49 Crosscut, No. 4 Belt and 50 Crosscut, No. 4 Belt. Rescue team personnel disconnected its power, and continued their exploration.

At 5:20 p.m., the rescue teams located the first victim, Terry Helms, in the track entry between 57 and 58 Crosscut, No. 4 Belt. By 5:50 p.m., the rescue teams had explored the previous seal locations inby 62 Crosscut, No. 4 Belt. At 6:18 p.m., rescue team members found that seal No. 10 in the No. 9 entry was destroyed. They continued to explore across the seal line and by about 6:47 p.m. had found that the other 9 seals were destroyed as well. They appeared to have been blown in an outby direction. The mine rescue teams finished exploring the seal area and then turned toward the 2nd Left Parallel section.

### **2nd Left Parallel Exploration**

At approximately 7:48 p.m., team members found the 2nd Left Parallel crew's abandoned mantrip at 10 Crosscut, No. 6 Belt. At 8:10 p.m., rescue team members found evidence of 12 SCSRs opened at 11 Crosscut, No. 6 Belt in the No. 7 entry. They also saw footprints heading in an outby direction. Rescue team members traveled outby in an attempt to follow the tracks, and to search

for any additional signs of the 2nd Left Parallel crew, but they turned up no further evidence. After 9:40 p.m., a rescue team explored to 17 Crosscut, No. 6 Belt and then retreated back to the FAB by traveling the belt entry.

At 11:12 p.m., the command center implemented a plan to extend the search distance beyond the normal 1,000 feet. The plan was to explore to the 2nd Left Parallel faces with a mine rescue team by extending communication using permissible handheld radios. The command center believed that the atmosphere in the mine, including in the 2nd Left Parallel, had stabilized to a point where it would not be life threatening. In an effort to locate the missing miners as quick as possible, a plan was developed that did not adhere to standard mine rescue procedure. Adhering to the standard procedure of advancing the FAB incrementally or airlocking would have added several hours to the search and rescue effort.

The teams had to stretch communications as far as possible. The teams were taking a risk in order to try to find the miners as soon as they could. By doing so, communications could be compromised by overextending the handheld radios' capabilities. Three of the four permissible radios were available. A fourth radio had become non-operational at some point during the rescue. McElroy rescue team members were contacted at the FAB and asked by the command center if they would go beyond normal rescue protocol. They agreed.

At 11:17 p.m., McElroy mine rescue team was authorized to search the entries toward the faces of the 2nd Left Parallel section. Two Tri-State team members were stationed on the track at 59 Crosscut, No. 4 Belt. One of those members had a permissible radio to relay communications back and forth to the McElroy team as they advanced into 2nd Left Parallel. The second Tri-State team member had a voice activated mine rescue hard line communication system to communicate to a person at the FAB. As the McElroy mine rescue team explored the 2nd Left Parallel section, they encountered water in the track entry that was approximately knee deep near 8 Crosscut, No. 6 Belt. At this point, the communication on the handheld radio that was used to talk with the Tri-State team member stationed at 59 Crosscut, No. 4 Belt began to break up. Therefore, a member of the McElroy rescue team was positioned near 8 Crosscut, No. 6 Belt to maintain communications with the Tri-State team member stationed at 59 Crosscut, No. 4 Belt. However, as the McElroy team continued to explore inby, the McElroy team member at 8 Crosscut, No. 6 Belt had to walk inby to 10 Crosscut, No. 6 Belt to maintain communication with the inby team members, and walk back outby to maintain communications with the FAB.

The distance from the track at 59 Crosscut, No. 4 Belt to 9 Crosscut, No. 6 Belt in 2nd Left Parallel was approximately 620 feet. The handheld radios become less reliable as the distance between users is increased or when the users are not in

direct line of sight of each other. The track in this area was not straight and it dipped near 8 Crosscut, No. 6 Belt, resulting in a lack of a direct line of sight.

As the McElroy team continued to advance toward the face, they would contact the McElroy team member at 10 Crosscut, No. 6 Belt with the information they wanted relayed to the surface. He would then travel through the water near 8 Crosscut, No. 6 Belt to communicate with the Tri-State mine rescue team member stationed at 59 Crosscut, No. 4 Belt. The Tri-State team member would relay the message to a team member standing next to him, who was manning the hard line device. This team member would then relay it to the FAB located in the No. 7 entry at 57 ½ Crosscut, No. 4 Belt. The team member at the FAB would communicate the information to the command center on the surface.

As the McElroy team approached the faces of 2nd Left Parallel they had to leave the track entry, losing sight and radio contact with the McElroy team member near 8 Crosscut, No. 6 Belt. This caused the outby team member to repeatedly wade through the water while trying to maintain communication with the inby rescuers and outby rescuers. He went back and forth numerous times during the rescue and recovery operation, but was not always able to maintain communication with both groups. The distance in the track entry from 10 to 23 Crosscut, No. 6 Belt was approximately 920 feet. This caused messages to break up and be difficult to understand.

The McElroy mine rescue team began searching the faces. They found a check curtain constructed across the No. 3 entry and heard a moan coming from behind it. The McElroy team member stationed between 8 and 10 Crosscut, No. 6 Belt heard someone say in an excited voice “there’s noises, there’s guys behind it ... we’ve got to go around another break.” He lost contact with them once they went around the crosscut. The team went through the curtain and found the miners. They began to administer first aid to the miner who was making the noise. Other rescue team members immediately went to each of the other eleven miners to make an assessment of their condition and to provide assistance if needed. It soon became apparent that McCloy was the only miner alive and they prepared him for transport to the FAB.

A MEU team member left the rest of the team in the barricade and traveled to the power center in the track entry at 23 Crosscut, No. 6 Belt to get a stretcher and to report their findings to the McElroy team member stationed between 8 and 10 Crosscut, No. 6 Belt. Using his handheld radio, he told the McElroy team member near 8 Crosscut, No. 6 Belt that they had “all 12 guys” accounted for and that “we have one alive.” He also asked for immediate help. The entry in which the MEU team member stood had several obstacles in the entry such as supply cars, which weakened the signals of the radios. In addition, the radios’ batteries were weak, and were scheduled to be changed in less than an hour.

The McElroy team member stationed near 8 Crosscut, No. 6 Belt stated that someone hollered over the radio “we need help, we’ve found them, we found all the men, we need help.” He recalled that the MEU team member told him “we need medical help. We have two people we’ve got down, we’ve got to have stretchers, we need help.” The McElroy team member shouted into his radio “they found them, they need help, there’s men down.”

The McElroy team member stationed near 8 Crosscut, No. 6 Belt was frustrated by the poor radio communications. He ran back and forth trying to improve reception. During this hectic time, the mine rescuers were quickly relaying information. The information communicated from the sender was not being repeated to verify the accuracy of what the recipient had heard. The McElroy rescue team member stationed near 8 Crosscut, No. 6 Belt had to run back and forth several hundred feet to maintain communications, and could not take the time to have people verify all the communications sent and received by him.

The mine rescuers at the FAB in 57 ½ Crosscut, No. 4 Belt stated that they received a message of “12 alive” over the headset from 59 Crosscut, No. 4 Belt and that they immediately called outside to the Command Center and repeated “12 alive.” The information communicated to the FAB from the team members inby was not confirmed by the FAB before it was relayed to the Command Center. After the Command Center received this information, they requested and received a confirmation from the FAB. At 11:46 p.m. on January 3, it was recorded in the Command Center log that the message “12 people alive” was received.

The mine rescue members at 59 Crosscut, No. 4 Belt stated that they heard the McElroy rescue team member near 8 Crosscut, No. 6 Belt say over the radio that “we found them alive” and “we need help now.” One Tri-State mine rescue member at the FAB and the two at 59 Crosscut, No. 4 Belt traveled to the face to help the rescuers. In addition, a MEU member and a WVMHS&T team member traveled to the face. This resulted in a further breakdown of the communication system. However, the McElroy team member continued to move between 8 and 10 Crosscut, No. 6 Belt trying to maintain communications. Upon reaching the barricade, those five rescue team members assisted in assessing the victims and in transporting McCloy.

The team members were all wearing heavy apparatus as they carried McCloy to the FAB. Team members took turns carrying the stretcher through knee-deep water and over concrete block rubble from destroyed stoppings. Some team members were running low on oxygen. As they were approaching 9 Crosscut, No. 6 Belt, one of them stated, “we’ve only got one alive ... we think we’ve only got one alive.” The McElroy team member stationed near 8 Crosscut, No. 6 Belt ran a couple of crosscuts outby and relayed back to 59 Crosscut, No. 4 Belt that

“they’ve only got one person alive.” He did not wait for a response and did not know if this information was received. He ran up and met the team members near 10 Crosscut, No. 6 Belt and helped carry McCloy to the FAB.

By approximately 12:30 a.m. on January 4, the rescuers reached the FAB. According to one rescuer, there were “a bunch of men ready to help, thinking there’s still 12” men alive. Rescue team members placed McCloy on a mantrip and transported him outside. Upon learning of the communication error, the McElroy team captain contacted the command center, and informed the command center that only one person was alive, and eleven were deceased. The command center then ordered all mine rescuers to exit the mine. By about 1:00 a.m., McCloy had been transported to the surface and placed in an ambulance. By about 1:20 a.m., all rescuers had exited the mine.

The command center debriefed the rescue teams. After the debriefing, the command center decided to send the Viper mine rescue team to the barricade to verify the initial findings made by the McElroy and Tri-State mine rescue personnel. The Viper Mine rescue team members, who were emergency medical technicians (EMTs), were provided stethoscopes to confirm the status of the miners in the barricade. The Viper rescue team and their back up, the Robinson Run rescue team, entered the mine around 1:38 a.m.

The Viper team also experienced communication problems. They were unaware of how the McElroy team had dealt with the gaps in communication, and planned to post a member of their team at 9 Crosscut, No. 6 Belt in 2nd Left Parallel Section to relay communications back to the FAB. However, they were unable to maintain communication with this member, and decided to take him to the barricade with them. As a result, the Viper team did not have communications with the FAB for a period of time.

After the EMTs on the Viper team confirmed that the other miners had perished, they could not report this information back to the FAB because they did not have a rescue team member with a radio near 10 Crosscut, No. 6 Belt to relay messages. Their confirmation did not reach the FAB until after the Robinson Run team came up to re-establish communications at about 4:14 a.m.

The command center and the rescue teams discussed the recovery of the deceased miners. Normal procedure would be for the area to be re-ventilated prior to any recovery, to limit the exposure of rescue team personnel to any hazards. However, rescue team members volunteered to re-enter the mine and, under apparatus, recover the deceased miners. By around 9:22 a.m. the victims had been recovered and transported to the FAB. Shortly thereafter, the mine rescue teams and the victims were transported to the surface. Appendix F contains the victim information data sheets.

## Rescue Borehole Chronology

Joseph Myers had been the Chief Engineer for the mine operator since July 29, 2005. He reported to Dunbar. He was responsible for the development of the coordinates for the drilling program, and in charge of planning the drilling of the boreholes during the rescue efforts at the mine.

Myers was notified of the accident at around 10:30 a.m. on January 2. Myers left his home and drove to the mine. While on the way, he made calls to Alpha Engineering (Alpha), an engineering group contracted to perform the mapping at the mine. Myers did not know exactly what would be needed. He asked Alpha to send a mapping grade handheld global positioning system (GPS)<sup>18</sup> and a survey grade handheld GPS, as well as a conventional survey.

Myers had in his possession a GPS unit that was accurate to plus or minus 30 to 50 feet. He tried to use the GPS unit numerous times by placing it in front of his car's windshield during his trip to the mine. Each effort was unsuccessful due to low signal strength from the satellites.

Gary Hartsog, President of Alpha, was notified by an Alpha employee of the accident around 10:45 a.m. At around 11:00 a. m., Hartsog tried to telephone Myers but was unsuccessful. Hartsog then telephoned Dunbar to obtain more details of the accident and determine how Alpha's resources should be used. Hartsog then contacted David Prelaz, an Alpha employee, and instructed him to work on completing an updated mine map for Myers.

Myers estimated that he arrived at the mine at around 11:30 a.m. He again checked the GPS but had virtually no signal. He entered the mine building and was briefed by Dunbar. At about 12:07 p.m., Myers again contacted Alpha, to determine when the mapping grade GPS would arrive, and to obtain an updated map of the mine. Alpha personnel downloaded a file copy of the updated mine map to a file transfer protocol site to which both companies had access. Myers then downloaded the file to a computer, which allowed him to start looking at potential areas for drilling.

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<sup>18</sup> A GPS uses a worldwide radio navigation system formed from 24 satellites and their ground stations. The system was designed for and is operated by the U.S. military. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity, and time. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock. Their accuracy varies depending on the receiver system deployed.



In addition, Myers used a planametrics map to assist in identifying surface structures, terrain and other surface features, to find potential drilling sites. At about 1:00 p.m., Myers contacted Hartsog and again requested a survey grade GPS unit. During this conversation, Hartsog informed him that both the mapping grade and survey grade GPS equipment would be sent.

Hartsog stated that the mapping grade GPS equipment was located in Sutton, West Virginia, and a person was ready to transport it to the mine. The survey grade GPS equipment required preparation time. Also due to the holiday, time was needed to organize people to operate and transport the equipment from Danville, West Virginia.

Based on the mapping information, Myers selected a drill site and forwarded it to mine management for approval. At about 1:35 p.m., Ty Coleman and Myers discussed with Satterfield and WVMHS&T personnel a proposal to drill a borehole into the 2nd Left Parallel section. Myers explained that the area above the 2nd Left Parallel conveyor belt feeder had the gentlest grade on which to develop a road and drill pad site. The hillside was much steeper at other potential drill sites further inby in the mine.

At approximately 2:07 p.m., Alpha employee Matt Ashley arrived on site with a map grade GPS unit. Ashley informed Myers that the map grade GPS had poor signal strength. Myers provided Ashley with a specific coordinate derived from the maps. Myers said that he would verify that coordinate when it was approved. He asked Ashley to locate that potential borehole site. At approximately 3:00 p.m., the mine operator obtained permission from the landowner for development of an access road and a borehole drill site. Myers estimated that the 2nd Left Parallel drill site was generated with the map grade GPS unit around 3:30 p.m. However, the initial drill site coordinates were not satisfactory due to poor signal strength. The software used by the GPS units requires that a certain number of satellites be in communication in order to complete a survey. The unit displays the Positional Dilution of Precision (PDOP) reflecting the signal strength and the number of satellites used. Weather, trees and structures may affect the PDOP. When the PDOP number is high, the results are less reliable. Alpha encourages its surveyors to use a PDOP that is in the range of 5 to 7. On the day of the accident, the surveyors were receiving a PDOP in the 16 to 18 range. Although the coordinates obtained were not deemed accurate enough to drill, construction of the pad and road began immediately. It was finished at about 6:30 p.m.

The mine operator's project engineer, Kermitt Melvin, arrived between 5:00 p.m. and 6:00 p.m. and began to assist Alpha personnel. At around 5:30 p.m., the command center discussed the proposed location of the borehole and gave

approval to drill the hole at the specified location, to within 20 feet of the coal seam.

An Alpha survey crew arrived on site about 6:00 p.m. They started a survey, working from permanent monuments at the mine and at the Spruce Fork No. 1 Mine, a nearby ICG mine. A survey grade GPS unit arrived on site at approximately 9:30 p.m. The surveyors attempted to use a real-time GPS<sup>19</sup>, which involved radio communication between GPS units. Adequate radio communication could not be established between the units to perform at an acceptable level. The surveyors informed Myers of the problem with the survey grade unit. Therefore, the surveyors resorted to using observations of GPS receiver units on permanent monument points at the Sago Mine and Spruce Fork No. 1 Mine to provide a baseline. Once those observations were made, the results were downloaded into a computer and processed. Calculations were made using a mathematical model to provide coordinates for two points in relatively close proximity to the drill site. That process was performed in the field on a laptop computer and was completed at about 11:00 p.m.

The conventional surveying method<sup>20</sup> was employed, using two points to locate the exact site for drilling. This was completed at 11:30 p.m. The original site of the drill hole determined by the mapping grade GPS was off by about 30 feet.

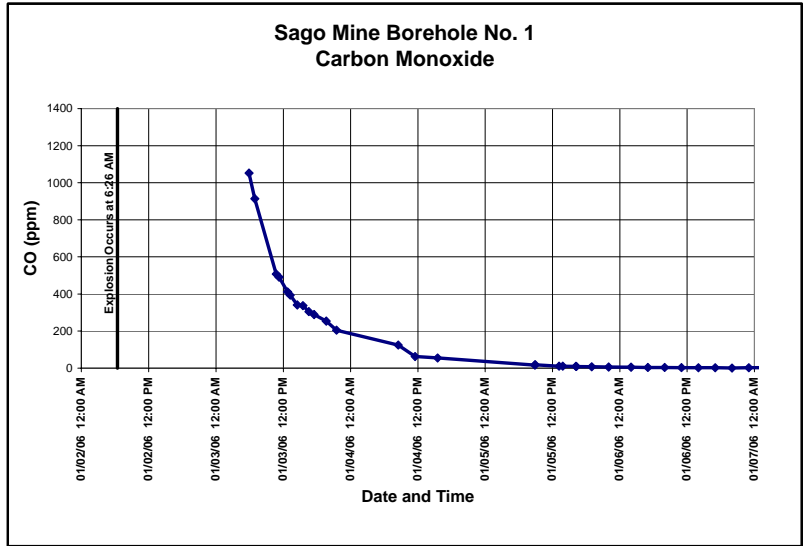
By approximately 2:00 a.m. on January 3, the drill site had been resurveyed and the drill rig mast had been plumbed by a survey crew. Drilling of Borehole No. 1 commenced at 2:45 a.m. Because the rescue teams had withdrawn from the mine, the borehole penetrated into the 2nd Left Parallel section at 5:35 a.m. at a depth of 258 feet. The borehole intersected the section at 23 Crosscut, No. 6 Belt in the No. 4 entry, over the conveyor belt feeder. The crew repeatedly struck the drill steel trying to get a response from the missing miners, but no response was heard. An air quality sample taken from the borehole at 5:53 a.m. indicated 1,052

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19 Real time GPS surveying techniques can provide measurements to the accuracy of a centimeter, over 10 kilometer baselines, by tracking five or more satellites and using real-time radio links between the reference and remote receivers.

20 Conventional surveying consists of an instrument such as a transit or a total station being placed over a point, and being used to accurately determine points and lines of direction (bearings) on the earth's surface. Maps or plans are prepared from the data generated.

ppm CO and 20.4% oxygen. Figure 5 illustrates the results of CO measurements obtained in Borehole No. 1. Appendix E contains the gas chromatograph analysis results for samples collected at the Borehole No. 1.



**Figure 5 - Borehole No. 1 Carbon Monoxide Results**

At 6:30 a.m., the crew lowered a camera into Borehole No. 1. The images displayed indicated that the area surrounding the conveyor belt feeder was relatively undisturbed. There was no sighting of the missing miners.

Two additional borehole sites were located to enable drilling to penetrate into 1st Left section and the outby end of 2nd Left Parallel section. The crew began drilling Borehole No. 2 at approximately 6:50 a.m., after the drill rig had been relocated from Borehole No. 1. Borehole No. 2 reached the hold depth of 360 feet, approximately 30 feet above the mine, at 2:24 p.m. The personnel in the command center decided not to complete the hole since rescue teams had advanced in the mains inby 1st Left. Borehole No. 2 was finished at a later date to aid in the recovery of the mine.

The drilling of Borehole No. 3 was started at about 2:35 p.m. but was stopped short of penetrating the mine because the hole was generating 60 to 80 gallons of water per minute, which it was feared could cause additional problems in the mine. This hole was never completed.

## MINE RECOVERY

The 1st Left and the area inby the 2 North Main seals had not been explored. The explosion caused extensive damage to the ventilation controls. Air quality monitoring at the No. 1 Drift Opening, Borehole No. 1, and eventually, through a series of additional boreholes was initiated. Air quality monitoring continued until the mine atmosphere was stable and safe for miners to re-enter the mine and restore ventilation.

On January 5th, Borehole No. 2 was completed into the track entry at 31 Crosscut, No. 5 Belt. It was used to monitor air quality in 1st Left. Boreholes No. 4 - 7 were drilled into the 2nd Left Mains. Borehole No. 4 was started on January 6th and completed on January 8th. Borehole No. 7, the last borehole drilled was started on January 17th and completed on January 19th. Boreholes No. 4 - 7 were used for air quality monitoring, dewatering, and/or ventilation. Dewatering of the 2nd Left Mains was started on January 12th and was not satisfactorily completed until January 20th.

The air quality analysis of the mine atmosphere remained favorable throughout the mine recovery. On January 21, 2006, with ventilation established to the boreholes at the inby end of the 2nd Left Mains, mine rescue/recovery teams entered the mine to examine and re-establish ventilation following the approved plan developed by the operator. In addition to establishing ventilation, some areas of the mine had to be dewatered. Dewatering required the restoration of portions of the underground mine electrical system.

After the mine rescue/recovery teams examined and established ventilation throughout the mine, the underground portion of the investigation commenced on January 26, 2006. Figure 6 is a photograph of a damaged ventilation control between the Nos. 6 and 7 entries at 59 Crosscut, No. 4 Belt found during recovery of the mine.



**Figure 6 - Damaged Stopping at 59 Crosscut, No. 4 Belt**



Figure 7 is a photograph of a damaged overcast in the No. 2 entry 58 Crosscut, No. 4 Belt found during recovery of the mine.

**Figure 7 - Damaged Overcast at 58 Crosscut, No. 4 Belt**

## INVESTIGATION OF THE ACCIDENT

MSHA's Administrator of Coal Mine Safety and Health appointed a team to investigate the accident at the mine. The team consisted of personnel from MSHA Coal Districts 2, 5, 7, and 11 and from Technical Support. The team utilized numerous resources, including personnel from MSHA Headquarters, Educational Field Services, Small Mines, and Technical Support. The Administrator appointed Richard A. Gates, District Manager of Coal District 11, as accident investigation team leader. A portion of the investigative team arrived at the mine on January 2, and the full team arrived at MSHA's Bridgeport, West Virginia field office by January 8.

The investigation was conducted jointly with WVMHS&T. The mine operator and two groups appointed by Sago miners, the UMWA and an employee group, also participated in the investigation. Appendix G lists the individuals who assisted with the investigation. Preliminary information and records were obtained from MSHA's Coal District 3 and from the mine operator.

The investigation consisted of both in-mine and out-of-mine activities. At the mine, the investigative procedures included mapping the entire mine, photographing the affected areas, and collecting physical evidence. The mapping of the entire mine is included in Appendices H-1 through H-9. The physical evidence was examined or tested on-site and/or later in an appropriate facility. The underground investigation could not begin until the rehabilitation work of drilling boreholes, dewatering, and restoring ventilation was completed. This delayed the investigation team from entering the underground mine until the work was completed. The entire underground mine was then examined and deemed safe for entry. The underground portion of the investigation began on January 26.

The investigative team identified numerous people who had knowledge relevant to the accident and conducted 80 interviews. These included officials of ICG, miners, a past employee, contractors, MSHA inspectors, WVMHS&T inspectors, mine rescue team members, and medical professionals. The interviews were conducted at the U.S. Bankruptcy Court and the U.S. District Court in Clarksburg, West Virginia; the Wingate Hotel in Bridgeport, West Virginia; the Renaissance Hotel in Morgantown, West Virginia; and MSHA offices in Bridgeport, Summersville, and Morgantown, West Virginia. Investigators conducted follow-up interviews of four previously interviewed witnesses. Additional information was obtained from contractors, and state and local authorities. Pertinent records were obtained and reviewed during the course of the investigation. The findings in this report are based on the information obtained during the investigation.

## **Mine Emergency Evacuation and Firefighting Program of Instruction**

MSHA approved the Mine Emergency Evacuation and Firefighting Program of Instruction on February 3, 2004. The mine operator later submitted two requests to revise page 3, which MSHA approved on May 3, 2005, and on November 8, 2005. These supplements changed the Emergency Alert Chart containing the persons to be notified in the event of an emergency. The program identified the dispatcher on duty as the "Responsible Person" in the event of a mine emergency involving a fire, explosion or gas or water inundation. The program stated in part:

"The responsible person shall have current knowledge of the assigned location and expected movements of miners underground, the operation of the mine ventilation system, the location of the mine escapeways, the mine communications systems, any mine monitoring system if used, and the mine emergency evacuation and firefighting program of instruction. The responsible person shall initiate and conduct an immediate mine evacuation when there is a mine emergency which presents an imminent danger to miners due to fire or explosion or gas or water inundation. Only properly trained and equipped persons essential to respond to the mine emergency may remain underground."

In addition to being designated as the responsible person, the dispatcher had other duties, including controlling the mine traffic underground and monitoring the AMS.

### **Notification**

The program included a list of persons that the dispatcher on duty was to notify immediately in the event of an emergency involving a fire, explosion or gas or water inundation. The list contained mine management, MSHA and WVMHS&T personnel.

Chisolm was on duty at the time of the emergency. He called Stemple at 7:00 a.m. and spoke to him for about 15 minutes regarding the events taking place at the mine. At about 7:15 a.m., Stemple was patched through to Jeffrey Toler who was underground assessing what had happened. Jeffrey Toler advised Stemple that he was not sure what had happened. He said that they had found the 1st Left crew, and they were bringing them to the surface. Jeffrey Toler related that the 1st Left Crew stated that there were several intake stoppings out, and that there was smoke and dust in the air as they traveled along the primary intake escapeway. When Stemple learned from Jeffrey Toler that there was dust and smoke in the air and that there had been no contact with the 2nd Left Parallel crew, he told Jeffrey Toler to re-establish ventilation as deep into the mine as he

could in an attempt to prevent a short circuit of air to the 2nd Left Parallel section.

Stemple made other calls before attempting to notify MSHA's Bridgeport, West Virginia Field Office Supervisor Kenneth Tenney at his residence. He left a message on Tenney's answering machine at 7:50 a.m. At 8:28 a.m., Stemple reached Bridgeport Office Supervisor James Satterfield at home. Satterfield issued a verbal 103(k) order at 8:32 a.m. Stemple notified the mine of the order at 8:35 a.m.

### **Evacuation of the Mine**

The Mine Emergency Evacuation and Firefighting Program of Instruction states as follows: "In the event that you are notified of or discover a mine fire, evacuation and fire fighting procedures shall begin immediately for those in the mine. Only those necessary to fight the fire shall remain in the mine. Those in outby areas or away from the mine phones will be notified by sending a messenger to their work area. From any area of any section the primary escapeway should be used first, and the alternate used only if the primary cannot (due to smoke, fire, water, roof fall, bad top, etc). The Dispatcher should be notified of your intention to evacuate by using the mine phone or the trolleyphone communication system."

Immediately following the explosion, Owen Jones directed his crew and the other miners present to evacuate the mine. The miners traveled the track entry to 37 Crosscut, No. 4 Belt and entered the primary intake escapeway. Owen Jones had a phone conversation with Chisolm and told him that something had happened. He said that he felt a force of air coming from the direction of 2nd Left Parallel section, and he thought there must have been an explosion. Wilfong was listening, and instructed Jones to take his crew to the primary intake escapeway and evacuate the mine. The miners were already evacuating and continued to do so.

Wilfong, Jeffrey Toler, Schoonover and Hofer entered the mine on a battery powered track mantrip. They did not take any gas detection instruments with them. They picked up John Boni along the track entry as they traveled underground. They found the miners that were evacuating near 27 Crosscut, No. 4 Belt. They all evacuated the mine with the exception of Jeffrey Toler, Schoonover and Owen Jones, who remained underground.

After taking the miners from the 1st Left crew to the surface, Wilfong and Hofer re-entered the mine with curtain, nails, boards, saws, detectors and a hard hat for Owen Jones and rejoined Jeffrey Toler, Schoonover, and Owen Jones. They then traveled inby to 32 Crosscut, No. 4 Belt. Even though they realized there had



been an explosion, they began making ventilation repairs. They installed check curtains in the crosscuts where stoppings had been damaged between the track entry and the intake entries up to and including 57 Crosscut, No. 4 Belt. Once the curtain was installed at 57 Crosscut, No. 4 Belt Jeffrey Toler, Schoonover and Wilfong observed the area inby 58 Crosscut, No. 4 Belt where the air velocity had diminished. Smoke was very thick and was not dissipating, hindering visibility. After making unsuccessful verbal attempts to contact the missing miners, they evacuated the mine.

## **SCSRs**

The Mine Emergency Evacuation and Firefighting Program of Instruction states, "Where emergency evacuation is required, personnel should immediately don their Person Wearable Self Contained Self Rescuer (PWSCSR)." The mine operator provided the miners with CSE-SR 100 Self-Contained Self-Rescuers.

Three miners working at outby locations did not don their SCSR units during their evacuation. Only seven of the 13 miners who were at the 1st Left track switch donned their SCSRs during the evacuation. The 12 miners in 2nd Left Parallel section donned their SCSR units while trying to evacuate. The miner found near 2nd Left Parallel switch had not donned his SCSR.

## **Belt Fire Detection System**

The mine used an AMS to detect gases that might result from a fire in the mine. The AMS was a Pyott-Boone Mineboss system that included a computer located on the surface in the dispatcher's office, which had multiple surface and underground sensors. The AMS required only one computer for the system to function. The system monitored the CO levels at all of its sensors, and showed belt operations and power status.

The program required that the system initiate fire alarm signals at a surface location where a responsible person was always on duty when persons were underground. The responsible person was to be trained in the operation of the AMS and the proper procedures to follow in the event of an emergency or malfunction. A map or schematic identifying each belt flight and the details of the monitoring system was displayed on the monitor.

Carbon monoxide sensors were required to be spaced along the conveyor belt at 1,000 foot intervals, and a sensor for the section tailpiece had to be between 50 and 100 feet inby or outby the section tailpiece depending on the direction of airflow. A CO sensor was required for each belt drive and tailpiece. However, where a belt drive discharges coal onto another belt tailpiece as a continuation of a belt conveyor system, without a change in direction and on the same split of

air, only one sensor was required. An air velocity of 50 feet per minute (fpm) or greater and a definite and distinct movement in the designated direction was required by the program. The system was required to have both visual and audible alarm signals. A visual or audible alert signal was required to activate when a sensor detected 10 ppm CO above the ambient level established for the mine. An audible alarm signal distinguishable from the alert signal was required when a sensor detected 15 ppm CO above the ambient established for the mine. The established ambient for the mine was 0 ppm.

When the system gave an alert signal (10 ppm CO), the program requires all persons to be withdrawn to a safe location outby the working places and action taken to determine the cause of the alert. When the system gave an audible alarm (15 ppm CO), all persons in the same split(s) of air were to be immediately withdrawn to a safe location outby the sensor(s) activating the alarm unless the cause was known not to be a hazard to the miners. If an alarm signal (15 ppm CO) was given at shift change, no one was permitted to enter the mine except those qualified persons designated to investigate the source of the alarm.

On January 2, 2006, at 6:04:54 a.m.,<sup>21</sup> a CO monitoring sensor at the 1st Left section tailpiece, identified as "station 1.99 1 left section" was taken off scan (manually turned off). At 6:05:05 a.m. the sensor initialized and was placed on scan (manually turned on). At 6:05:10 a.m. the system alarmed and indicated a reading of 26 ppm CO.

According to the CO monitoring log, problems with this sensor had been occurring off and on since December 9, 2005 when the sensor was calibrated. Several hours after calibration, the device reported an event that generated an alarm indicating a reading of -1 ppm, and the alarm reset a few seconds later. Between December 10, 2005 and December 31, 2005, several events were recorded showing that the sensor lost communication with the Master Control Station on the surface for periods of 5 seconds to 1 hour and 19 minutes.

Between December 15, 2005 and December 31, 2005, there were numerous entries in the CO event log indicating that the alarms and latch resets were increasing. The maximum "Alarm Latch Set" value was 26 ppm on December 31, 2005 and the maximum recorded CO value was 38 ppm on December 30, 2005. Additionally, several entries in the log during this time period indicated that the device had lost and regained communications.

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<sup>21</sup> The record of the AMS times was 4 minutes and 56 seconds fast. The times shown are corrected times.

Two methods are used to reset the warning and alarms after they have activated or latched. When the CO level recedes to a point below where the alarms are set, the sensor will reset automatically if the system is in the auto reset mode. If it is not in the auto mode it can be reset from the surface or it can be reset by personnel at that sensor's location. This CO sensor was in the automatic reset mode when inspected during the investigation.

The value reported by the sensor at Station 1.99 at the 1st Left section tailpiece was not correct. With clean air applied, the unit reported a value of 26 ppm CO. When CO calibration gas containing 50 ppm was applied, the sensor reported 74 ppm. The difference between the 'zero' and 'span' points was 48 ppm. When coupled with the event log readings showing: (a) steadily increasing alarm readings, and (b) the calibration adjustment attempted on December 15, 2005, it appears that the sensor had a zero drift.

The connections between the CO sensor and the remote alarm on the section were incorrectly wired. The remote alarm could not be activated by the attached sensor or from the surface. Additionally, when properly calibrated and the wiring to the alarm unit on the section was corrected, this CO sensor would cause the attached alarm to give audible and visual warnings continuously in clean air.

In conclusion, the CO sensor with address station 1.99 1 left section was communicating with the system on February 1, 2006 when inspected during the investigation. However, the unit was not measuring CO within acceptable limits. The remote alarm would give an audible and visual warning when the test buttons were pressed on the device, but it would not provide warning signals at the section loading point when actuated by the CO sensor or the surface master control station. It was determined that the system was malfunctioning because the wiring between the CO sensor and the alarm was incorrect. The data suggests that the sensor and remote alarm did not function properly at the time of the explosion. Furthermore, the data suggests that some corrective action had been attempted in the early morning hours of December 31, 2005, and that the system operator had attempted to reset the device at approximately 6:05 a.m. on January 2, 2006. Appendix I contains an executive summary of "Investigation of Pyott-Boone Electronics MineBoss Monitoring and Control System." The Ventilation Plan and the Mine Emergency Evacuation and Firefighting Program of Instruction contained guidelines for the installation, use and maintenance of the system, and outlined the appropriate responses to the signals provided by the system. The plan and program also outlined procedures to follow if the system was partially or completely inoperative.

The program states "When the carbon monitoring warning system gives an audible alarm at 15 ppm above the established ambient level at shift change, no

one shall be permitted to enter the mine except qualified persons designated to investigate the source of the alarm.” At 6:05:01 a. m. the sensor at Station 1.99 at the 1st Left section tailpiece indicated a reading of 26 ppm CO. The 2nd Left Parallel crew had entered the mine about 6:00 a. m. The program required that, “If miners are enroute into the mine, they shall be held at, or be withdrawn to, a safe location outby the sensor(s) activating the alarm.” The 2nd Left Parallel crew’s route of travel and eventual work location was not affected by this alarm, and they continued into the mine. There was no indication that they were contacted. The 1st Left crew entered the mine about 6:05 a. m. There was no indication that any efforts were made to investigate the alarm. The Program further states “When a determination is made as to the source of the alarm, and that the mine is safe to enter, the miners shall be permitted underground.”

A responsible person was required to be on duty at all times when miners were underground. The person was to be situated so that he could see or hear the alert and alarm signals. As noted above, the responsible person for the system was to be trained in the operation of the AMS and in the proper procedures to follow in the event of an emergency or malfunction and, in that event, was to take appropriate action immediately. However, some dispatchers at the mine were unaware of the correct alert and alarm levels, or of the proper procedures to follow when those alert and alarm levels were reached. In addition, dispatchers were improperly using the AMS to signal miners on the working sections to answer the mine phone.

### **Barricading Instructions**

The Mine Emergency Evacuation and Firefighting Program of Instruction provided guidelines for barricading when miners are entrapped by toxic gases from fires or explosions. The program stated that the miners should collect tools, timbers, boards, brattice cloth, water, dinner buckets, self-contained self rescuers and whatever else may be useful. Barricade construction should begin as soon as possible. A place of several hundred feet of entries or rooms should be chosen to provide as much oxygen as possible and the area should be made air tight in an attempt to shutout toxic gases thereby creating a toxic gas-free atmosphere. Theoretically, an average size person breathes approximately one (1) cubic yard of air per hour. A rule of thumb is that about 8 feet of entry length should provide air to sustain one person for one day. The ventilation current outby the barricade should be shut off or short-circuited as soon as possible by opening personnel doors or knocking out permanent stoppings or overcasts. If a series of controls are built (air lock) to ensure an air tight seal, a sign should be placed outby the first control indicating persons are behind the barricade. To conserve oxygen, persons should remain as quiet as possible, near the floor and separated by several feet. However, one person should walk around occasionally to mix the air. Flame safety lamps should be extinguished and cap lamps should be

turned off after the barricade is completed. Persons should listen for 3 shots from the surface. They should return a signal by pounding on the mine roof 10 times. The persons should repeat pounding on the mine roof about every 15 minutes. This should be repeated until they hear 5 shots which would indicate that they have been located. Oxygen cylinders, such as those used for oxygen/acetylene cutting torches, could provide an additional source of oxygen in a barricade.

### **Barricading**

The erection of a barricade by miners who cannot escape after an explosion or fire can be a life-saving measure as a last resort. Miners who have been physically blocked by an explosion may seal themselves promptly behind well-located and well-constructed barricades, bulkheads, or stoppings.

Since the first records were maintained in 1909, the United States Bureau of Mines (USBM) has recorded that lives have been saved by barricading.<sup>22</sup> Explosions change the mine atmosphere and create high concentrations of CO, low levels of oxygen, and other gases in a short period of time. A well-constructed barricade should be practically airtight to prevent ingress or egress of air. The miners who go behind the barricade are dependent upon the air within this enclosed area.

Barricading was an option of last resort after all avenues of escape to the outside were believed to be cut off. After the 2nd Left Parallel crew encountered smoke and gases during efforts to exit the mine on the mantrip, they attempted to find other possible exits. When these attempts failed, they retreated to the section and tried to isolate themselves from poisonous gases by building a barricade. Records indicated the 2nd Left Parallel crew had been trained in the methods of barricading and location of barricading materials during annual refresher training.

The miners knew that ventilation controls had been blown out. McCloy recalled Martin Toler instructing the miners to construct a barricade from curtains. McCloy stated they decided to use curtain from the face area since some miners did not have SCSRs, and because it would take more time and effort to use concrete blocks. McCloy indicated that they attempted to construct the barricade to keep the smoke out. He further described that initially there was some smoke inside the barricade, but that the smoke faded and the air cleared a little bit.

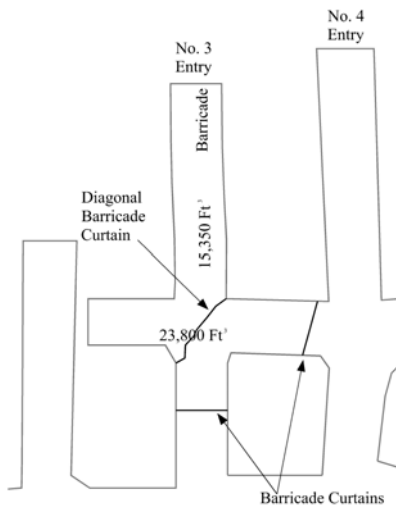
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<sup>22</sup> Saving Life By Barricading In Mines And Tunnels At Times Of Disaster, United States Department of Commerce, Information Circular 6701, Harrington, D. et al.

However, James Bennett wrote at 11:40 a.m. that “we have air right now but the smoke is bad.”

Experiments by the USBM show that a man in a confined space needs about a cubic yard of normal air each hour. The barricade location selected by the miners was inby and included the last open crosscut of the No. 3 entry. The width of the crosscut between the Nos. 3 and 4 entries was about 17 to 20 feet. The width of the No. 3 entry outby the last open crosscut was about 18 to 20 feet. Curtains were installed across these locations. A diagonal curtain was installed from the right rib of the inby corner, to the left rib of the outby corner, in the No. 3 entry.

The diagonal curtain was approximately 29 feet in length from rib to rib and balled up on the outby end, according to the captain of the McElroy mine rescue team. The volume of the larger area, (curtain in the crosscut and the curtain in the entry to the face) was about 23,800 cubic feet. The volume of the smaller area, (diagonal curtain to the face) was 15,350 cubic feet. The larger area calculated into cubic yards for 12 miners would be 73 cubic yards per miner. The smaller area for 12 miners would be only 47 cubic yards per miner. This shows that the miners had enough air to sustain them for at least 47 hours if they remained in the smaller area within the barricade and if normal air was in the barricade. This is about 6 hours longer than it took for mine rescue teams to reach the barricade. Figure 8 is a drawing of the barricade.



**Figure 8 -Drawing of Barricade**

The CO concentration at the time the barricade was constructed is unknown. A borehole was drilled into the No. 4 entry in the area of the conveyor belt feeder at 5:35 a.m. on January 3, 2006. The first bottle sample analysis taken from the borehole showed 1,052 ppm of CO. The captain of the McElroy mine rescue team was the first person to enter the barricade sometime after 11:30 p.m. on January 3, some 41 hours after the explosion. He and an MSHA mine rescue

team member stated that the CO level was 300-400 ppm around and in the barricade area, at the time they found the barricade. The CO level at the borehole at 9:30 p.m. was 205 ppm.<sup>23</sup> According to these witnesses, the curtain across the crosscut between the Nos. 3 and 4 entries was loosely hung and open about one foot at the inby side. The diagonal curtain was open about one foot at both ends when the barricade was entered. They did not notice what was used to hang the curtains (nails, wire, etc.). They also said no coal or other sealing material was on the bottom of the curtain to weigh it down for a tight fit. Other possible barricading material was present on the supply car in the track entry at 17 Crosscut, No. 6 Belt, including four pallets of 6-inch concrete blocks, mortar, wedges, headers and cap boards. Fifty 6-foot and sixteen 8-foot posts, and spray sealant were located at 5 Crosscut, No. 6 Belt.

### **Carbon Monoxide Poisoning**

Carbon monoxide is a colorless, odorless, and highly toxic gas. It is formed as a by-product of burning organic compounds. The composition of the mine atmosphere after the explosion would have been dictated by the methane concentration and quantity, the uniformity of the methane mixture, the amount of coal dust ultimately involved in the explosion, and to a lesser extent other variables such as humidity, turbulence and other materials which were in the explosion zone. NIOSH, formerly the USBM, has provided research data on the composition of an atmosphere after a methane or coal dust explosion in the laboratory. The data indicated that if a methane concentration of 12% was present and if methane was the sole fuel source prior to the explosion, CO could be formed to a concentration as high as 80,000 ppm (8.0%). The data also indicated that if coal dust was the sole fuel source involved in the explosion at a concentration of one ounce per cubic foot, CO could be formed to a concentration as high as 46,000 ppm.<sup>24</sup> Also, NIOSH has conducted numerous explosion tests at its experimental mine and collected mine atmosphere samples after the tests. This data indicated that the CO concentration could reach as high as 117,000 ppm (11.7%).<sup>25</sup>

When CO is inhaled, it is diffused into the bloodstream and displaces oxygen from the hemoglobin that is found in red blood cells. It combines with hemoglobin about 200 to 250 times faster than oxygen. Inhalation of even small

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<sup>23</sup> The CO reading of 205 ppm was determined using a gas chromatograph. The hydrogen level was 136 ppm. Hydrogen is an interference gas that often causes the handheld detectors to read high.

<sup>24</sup> The Explosion Hazard in Mining, United States Department of Labor, MSHA Informational Report 1119, (1981), John Nagy, page 63.

<sup>25</sup> *Id.*, page 64.

amounts of CO can cause oxygen deficiency, known as hypoxia. Hypoxia may cause headaches, nausea, dizziness, fatigue, confusion, drowsiness, rapid breathing, increased pulse rate, vision problems, chest pains, convulsions, seizures, loss of consciousness, and may eventually cause death.

A person with elevated levels of carboxyhemoglobin or CO poisoning is often described as anemic, due to a low hemoglobin level available to bind to oxygen. Carbon monoxide increases the release of nitrous oxide in the system. Nitrous oxide causes a drop in blood pressure by interfering with cellular respiration, resulting in a decrease in the amount of blood flow to the brain, as well as a reduction in the amount of oxygen in the blood that is flowing. Reduced oxygen in the blood also alters the hemoglobin molecule so that it will not release oxygen as readily to the cell.

Carboxyhemoglobin is the amount of hemoglobin attached to CO, and is measured in blood to detect CO toxicity. At 20% and above, a person starts to have trouble with motor skills. They may be conscious but nauseated, and begin suffering a headache. Thinking skills and even emotions may start to deteriorate beyond a 20% carboxyhemoglobin level. At 30% to 40%, the person may be quite confused, experience difficulty performing tasks and, depending on their risk factors, suffer unconsciousness. Carboxyhemoglobin that is greater than 80% is immediately fatal. Tables 5 and 6 summarize the effects of carbon monoxide.

Not all individuals will respond similarly to the effects of CO inhalation. Certain risk factors must be considered, for example, a person with moderate cardiac or pulmonary disease, emphysema or anemia, or a long-term smoker, may respond more severely to a lower level of CO than someone without those conditions exposed to a higher level. The deprivation of oxygen caused by CO poisoning causes a variety of physical ailments. There are also neuropsychological problems associated with the poisoning.



Table 5 - Summary of Toxic Effects Following Acute Exposure to Carbon Monoxide<sup>26</sup>

Carboxyhemoglobin In Blood (%)	Signs and Symptoms
<2%	No significant health effects
2.5%-4.0%	Decreased short-term maximal exercise duration in young healthy men
2.7%-5.2%	Decreased exercise duration due to increased chest pain (angina) in patients with ischaemic heart disease
2.0% - 20.0%	Equivocal effects on visual perception, audition, motor and sensor motor performance, vigilance and other measures of neurobehavioral performance
4.0%-33.0%	Decreased maximal oxygen consumption with short-term strenuous exercise in young healthy men
20%-30%	Throbbing headache
30%-50%	Dyspnea, dizziness, nausea, weakness, collapse, coma
> 50%	Convulsions, unconsciousness, respiratory arrest, death

Individuals who have high to low levels of carboxyhemoglobin in their body may seem fine initially, but may experience memory loss a few days later. This delayed reaction is neurologic syndrome and is associated with CO poisoning. These delayed symptoms, including psychological disability, may occur anywhere from forty-eight hours to months and even years afterwards.

The hippocampus (memory), the basal ganglia (motor function) and the cerebellum (balance) are referred to as watershed areas because they are located deep within the brain and at the end of the blood circuit. Collateral circulation is the process of providing blood flow through an intricate network of vessels from healthy areas of the brain to areas that have been damaged. This network of blood vessels branches deep into the brain, becoming smaller and smaller until they reach the end of the blood circuit. A person with a significant degree of CO poisoning will be affected in these three areas of the brain.

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<sup>26</sup> [www.camr.org.uk/chemicals/compendium/carbon\\_monoxide/acute.htm](http://www.camr.org.uk/chemicals/compendium/carbon_monoxide/acute.htm)

**Table 6 - Summary of Toxic Effects Following Acute Exposure to Carbon Monoxide<sup>27</sup>**

<b>PPM CO in Air</b>	<b>Percent CO in Air</b>	<b>Symptoms Experienced by Healthy Adults</b>
Less than 35 ppm	0.0035%	No effect in healthy adults
100 ppm	0.01 %	Slight headache, fatigue, shortness of breath, errors in judgment
200 ppm	0.02%	Headache, fatigue, nausea, dizziness
400 ppm	0.04%	Severe headache, fatigue, nausea, dizziness, confusion, can be life-threatening after 3 hours of exposure
800 ppm	0.08%	Headache, confusion, collapse, death if exposure is prolonged
1500 ppm	0.15%	Headache, dizziness, nausea, convulsions, collapse, death within 1 hour
3000 ppm	0.3%	Death within 30 minutes
6000 ppm	0.6%	Death within 10-15 minutes
12,000 ppm	1.2%	Nearly instant death

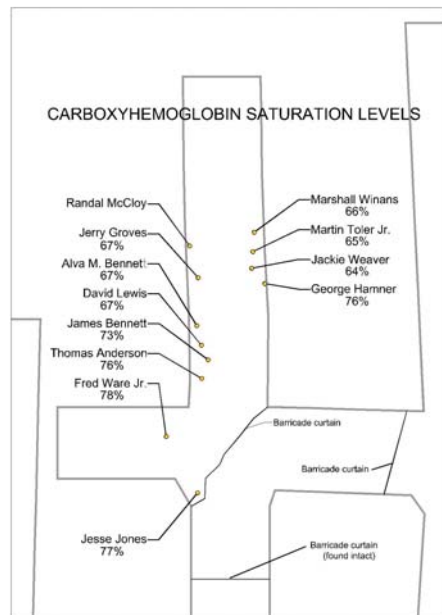
Injury to the hippocampus causes varying degrees and types of memory loss or memory impairment. The most common is anterograde amnesia (memory dysfunction). Anterograde amnesia usually begins at the time of the exposure. There is difficulty forming new memories. A person can learn and recall how to do simple tasks. A person with severe CO poisoning that has a hippocampus injury will have difficulty remembering the contents of a conversation ten minutes later. Retrograde amnesia causes loss of memory of events from a fixed period in the past. Some affected individuals may suffer the loss of three years worth of memories, while others may be unable to remember a 15-year period.

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<sup>27</sup> Washington State Department of Labor ,[www.Ini.wa.gov/Safety/Topics/AToZ/carbon](http://www.Ini.wa.gov/Safety/Topics/AToZ/carbon)

According to Dr. Raymond Roberge, M.D., depending on the degree of exposure, most victims will have some memory of events that occurred before the onset of amnesia.

The cause of death for all of the victims was carbon monoxide intoxication/poisoning. Helms was found near the mouth of the 2nd Left Parallel section and had a carboxyhemoglobin saturation of 78%. The deceased miners found in the barricade had carboxyhemoglobin saturation levels ranging from 64% to 78%. The levels do not appear to be age or size dependent but indicate a trend relative to their distance from the barricade curtains with McCloy, the surviving miner, being the furthest in by. Figure 9 shows the location of the miners in the barricade and their carboxyhemoglobin saturation levels.



**Figure 9 - Location of Miners and Their Carboxyhemoglobin Levels**

## Self-Contained Self-Rescuers

### Introduction

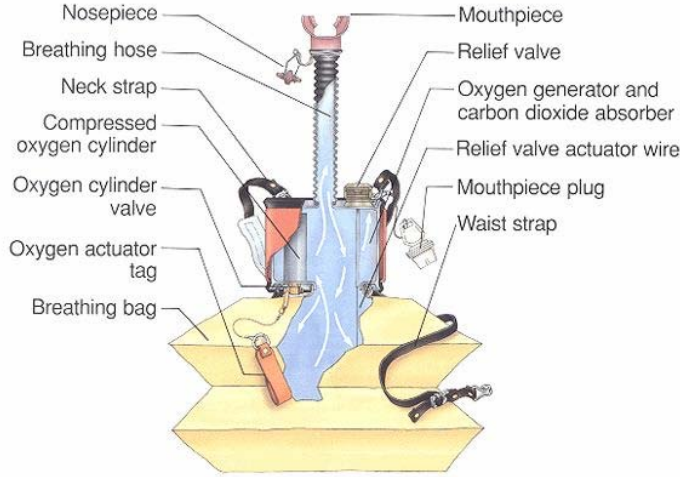
Section 75.1714 requires the mine operator to make available to each miner an approved self-rescue device, which is adequate to protect the miner for one hour or longer. The operator must provide for training, proper inspection, testing, maintenance and repair of the units.



The mine operator supplied a CSE SR-100 person-wearable self-contained self-rescuer (SCSR) to each miner. These units were manufactured by the CSE Corporation in Monroeville, Pennsylvania. The MSHA/NIOSH approval number is TC-13F-239. Figure 10 shows the CSE SR-100.

**Figure 10 - CSE SR-100**

The SR-100 provides about 100 liters of usable oxygen for a rated duration of 60 minutes. The unit uses a bi-directional rebreathing system in which the exhaled gas makes multiple passes through a carbon dioxide/oxygen generation canister where carbon dioxide is absorbed and oxygen is generated before the gas can be returned to the user.<sup>28</sup>



Potassium superoxide ( $KO_2$ ) is used to produce oxygen, as well as absorb carbon dioxide. It is yellow solid but turns a dark grey as it is reacted. Lithium hydroxide ( $LiOH$ ), which is a white solid, is also used to scrub the carbon dioxide.

**Figure 11 - Components of the SR-100 SCSR**

The unit is certified for one hour of operation based on 42 CFR Part 84 and the maximum service life is 10 years. The SR-100 is designed to quickly isolate a miner's respiratory system from a potentially dangerous atmosphere. It is approved as an escape-only self-contained breathing apparatus and should not be used for rescue, firefighting or underwater breathing. Figure 11 shows the components of the system.

Initially, the unit should be removed from the carrying pouch. The tab on the security band is pulled, thereby releasing the band and the top and bottom covers of the unit to open the unit. The manufacturer indicates that after the unit

<sup>28</sup> Donning Procedures for Person-Wearable Self Contained Self Rescuer, CSE Corporation.

is opened, a properly trained user should be able to activate the oxygen, insert the mouthpiece, and put on the nosepiece in approximately 10 seconds. The oxygen is released from the oxygen cylinder by pulling on the oxygen actuator tag. The miner will hear the faint hiss of the oxygen being released from the cylinder for a few seconds. He should also notice the breathing bag fill. It is important that the mouthpiece plug remains in the mouthpiece during this operation as the oxygen can escape into the atmosphere through the mouthpiece rather than fill the breathing bag. If the breathing bag does not fill for any reason, such as the failure of the compressed oxygen cylinder or the oxygen vents from the unit as stated above, the SCSR can be manually started. This procedure requires that the miner inhale ambient air and exhale into the unit three to six times. The miner then puts on the nose clips to completely close the nostrils, puts on the goggles, adjusts the unit's straps, replaces his hard hat and evacuates.

An SCSR is a closed-circuit breathing apparatus which provides safe, breathable air, independent of the ambient atmosphere. It is designed to be used only for escape from an un-breathable atmosphere. Once donned, an SCSR must not be removed, even to talk, until safety is reached, or its oxygen supply is exhausted.

Attempting to conserve, save, or share the oxygen supply in an SCSR, by removing the mouthpiece, may expose a miner to the risk of breathing toxic atmosphere. Re-inserting the mouthpiece, or trying to restart the SCSR provides no means to filter, absorb, or otherwise protect the wearer from what they have already inhaled.

Repeated donning, re-inserting the mouthpiece, or trying to restart the SCSR could also interfere with its proper function. The SCSR's performance may be compromised. The SCSR may not restart, or provide protection for its rated duration.

### **Daily Inspection**

The SCSR must be inspected for damage and for the integrity of its seal each time it is worn or carried by a miner. The unit should be checked daily to insure that it is less than 10 years old, the security band is secure, the top and bottom moisture indicators are blue, the temperature indicator (if applicable) is white, the top and bottom covers are properly aligned, and that there are no signs of significant damage. Any unit that does not meet these criteria must be removed from service. There is no requirement to document the results of the daily inspection, unless the unit is removed from service.

## 90 Day Inspection

On November 23, 1998, MSHA and NIOSH notified the mining industry of a potential problem on some CSE SR-100 SCSR devices. MSHA and NIOSH had tested a large number of SCSRs and found that some units produced a higher than normal level of carbon dioxide (CO<sub>2</sub>). In order to identify the SR-100s most likely to exhibit a higher than normal level of CO<sub>2</sub> and remove them from service, an Acoustic Solids Movement Detector (ASMD) test was incorporated into the required 90 day examination of SR-100s. Any unit that failed this test was to be taken out of service.<sup>29</sup>

The percentage of carbon dioxide in the air affects a miner's breathing. In air, it is about 0.03%. Miners exposed to about 0.5% carbon dioxide in air may breathe a little deeper and faster, that is, their lung ventilation would increase. Their lung ventilation may double when 3.0% carbon dioxide in air is present. When the carbon dioxide levels in air reaches 10%, a miner may only be able to tolerate it for a few minutes even if he is at rest. A mixture of 10% carbon dioxide in air contains about 18.9% oxygen.<sup>30</sup>

SCSRs shall be tested in accordance with approved instructions. The person making the test shall certify by signature and date that the tests were done. The manufacturer states the SR-100 must be tested with the ASMD at least once every 90 days. Training materials are provided by the manufacturer. The test is conducted by attaching the ASMD to the front center of the SR-100. The test can be performed by shaking the unit up and down, several times. A LED indicator on the ASMD will inform the user if the unit passes the test. Any unit which does not pass the test must be removed from service.<sup>31</sup>

The ASMD test is a Pass/Fail test. It does not distinguish the precise condition of damage, nor predict to what degree the performance will be degraded. Nor does the ASMD test apply to the functioning of the oxygen startup cylinder. SR-100s that fail the test may not provide an acceptable level of life support. Since the

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<sup>29</sup> This information is described in more detail in Program Information Bulletin (PIB) No. P99-5 dated April 5, 1999, which is outdated. The PIB states that "although the affected devices will continue to provide protection and miners should not suffer any long term health effects while wearing the device, self-rescue devices that exhibit a higher-than-normal level of CO<sub>2</sub> do not conform to the approval requirements and must be removed from service." The current version of the ASMD Instruction Manual describes the testing methodology for the Daily Visual and 90 day inspection criteria but does not discuss the specific reasons for the test.

<sup>30</sup> Mine Gases, Mine Enforcement and Safety Administration, p 11.

<sup>31</sup> Daily Visual and 90 day Inspection Criteria, CSE Corporation.

extent of damage cannot be known, all SR-100s failing the ASMD test must be removed from service.

## **Training**

Miners are required to be trained on all types of SCSRs used at the mine, and a record kept of that training. The training must include instruction and demonstration in the use, care and maintenance of an SCSR. The training must also include complete donning procedures. This training must be provided during the Training of New Miners, Experienced Miners Training, or Annual Refresher Training. A review of these records was completed for each miner that was underground on January 2.

## **Recordkeeping**

Various records were reviewed to determine which SCSR was assigned to each miner. These include the 90 day inspection record of the SCSRs maintained by the mine operator for the Sago Mine and the Spruce Mine, records that were obtained by MSHA inspectors during inspections in 2004 and 2005, purchase orders, and information obtained from the mine operator. It was not always possible to determine which SCSR was assigned to which miner underground on January 2. Additionally, because it was possible for miners to switch SCSRs, it is not possible to conclusively state that a particular SCSR was assigned to, carried by or used by that miner.

## **Evaluation**

The SCSRs that were recovered were sent to NIOSH's National Personal Protective Technology Laboratory (NPPTL) in Pittsburgh, Pennsylvania for evaluation. These evaluations were conducted blind, that is, during the evaluation, NPPTL and MSHA personnel had no prior knowledge of the circumstances surrounding the use or deployment of any particular unit, other than the only unopened SCSR belonging to Terry Helms. This evaluation included a visual inspection for any irregularities, such as significant damage. It was not possible to state conclusively that the units evaluated by NIOSH would have passed or failed visual inspection prior to the explosion. For example, NIOSH could not evaluate the condition of the seals and the top and bottom covers, the moisture or temperature indicator, and the security band. The condition of the breathing hose and bag, as well as the condition of the other components was evaluated. An observation of the activation of the start-up oxygen was made. This observation can determine whether the oxygen cylinder was activated, but it cannot determine if the oxygen bottle was full. The evaluation cannot determine if the oxygen exited the unit through an open mouthpiece during the donning process. A visual estimate of the amount of

chemical used was completed, and a determination of whether the unit produced oxygen was made on the opened SCSRs. The visual estimate of the amount of chemical used is related to the amount of oxygen the unit produced. This estimate is based on color change of the KO<sub>2</sub> in the chemical bed. A performance test on the Breathing and Metabolic Simulator was conducted on the unopened SCSR.

In order to supplement the visual estimates of oxygen utilization, chemical analyses were performed at the laboratories of CSE and an independent laboratory, Alternative Testing Laboratories, Inc (ATL). The investigation team requested that CSE utilize a modification of their quality control procedures for analyzing pure KO<sub>2</sub> samples to obtain estimates of oxygen utilization. The modification dealt with the handling and preparation of the sample, and did not alter the analytical method used. The procedure was replicated at ATL and witnessed by MSHA, for verification purposes. The results from the three analyses differ due to the fact that they are estimates. Visual estimates took into account the characteristics of the whole chemical bed. This type of analysis is especially useful when most of the chemicals have been utilized and the bed material is "fused" or stuck together. The chemical analyses use a representative sample from the un-fused chemicals. The material was mixed in an attempt to achieve a homogeneous mixture. The results obtained from this procedure should be regarded only as an estimate of the utilization of the chemical bed by the wearer of the SCSR. Exposure of the chemical to moisture or carbon dioxide will be detected as bed usage by this procedure. Exposure can occur between the time the units were worn and the time that the canisters were opened and evaluated by the laboratory.

A laboratory test was conducted in 2006 to determine how much of the chemical bed was used when a CSE SR-100 SCSR was activated and left exposed to the atmosphere. During the test, three SR-100s were opened, activated, and left with the mouthpiece plug removed for a 48 hour period. After 48 hours, the units were placed in plastic bags. These units were about 1 year old. The relative humidity in the atmosphere was 40% to 53% and the temperature was 70 to 75 degrees Fahrenheit. The units were then tested by CSE. The results of the test indicated that approximately 3.3%, 3.1% and 1.5% of the chemicals in the unit had been depleted.

### **Miners Working Outby 1st Left**

At the time of the explosion, John Boni, Pat Boni and Jamison were working in outby areas. After the explosion, they evacuated the mine without donning their SCSRs. Records indicated which SCSR was assigned to each of the three miners. It was not possible to state conclusively that each miner was carrying the SCSR that had been assigned to him at the time of the accident. The mine operator's



records indicated that the 90 day inspection was completed for two of the three SCSRs. One of the three miners had received training on the SCSR within one year. John Boni stated that he had signed a training form without taking the training. Pat Boni indicated that he did not don the unit as part of the training, and his training was given by a person who is not listed as an approved instructor for Experienced Miner Training. Records indicated the last Experienced Miner Training Pat Boni received from an approved trainer occurred more than one year prior to the accident.

John Boni - The mine operator's inspection records indicated SCSR 106186 was assigned to John Boni. The last 90 day inspection occurred on November 14, 2005. This SCSR was manufactured in July of 2004. During the evacuation, John Boni did not don his SCSR. He was near the pump at 22 Crosscut, No. 3 Belt when the explosion occurred. He indicated "there was no smoke or --- there was, like I said, mainly rock dust in the area that I was in." He stated that his last training on the unit "would have been probably a year and a half ago." He indicated that he missed a scheduled training class, but signed a form stating that he had received the training. The records show that he had Experienced Miner Training at the Sago Mine on October 11, 2004. The training form indicated, "Hands on SCSR/Tour." The records showed he had Annual Refresher Training at the Sago Mine on October 7, 2005.

Pat Boni - The mine operator's inspection records indicated SCSR 100991 was assigned to Pat Boni and the last 90 day inspection occurred on November 16, 2005. Although the unit was manufactured in December of 2003, the mine operator's records show it was manufactured in November of 2004. Pat Boni was in the belt entry near No. 4 Belt drive when the explosion occurred. During the evacuation, he did not don his SCSR. He stated that he "knew I was in good air," and that there was never a time that he smelled or saw smoke. He stated that he had training on the unit. However, he did not don the SCSR as part of the training exercise. He stated, "he showed us how to do it." The records show that Pat Boni had Experienced Miner Training at the Sago Mine on December 29, 2004. The training form indicated, "Hands on SCSR/Tour." The records show that he had Experienced Miner Training at the Sago Mine on July 5, 2005. The training form was signed by a person who was not listed as an approved instructor for Experienced Miner Training.

Jamison - The Spruce Mine inspection records indicated SCSR 91947 was assigned to James F. Jamison. The 90 day inspection occurred on February 14, 2005. It was manufactured in March of 2002. There were no records from the Sago Mine indicating which SCSR was assigned to Jamison, or that the 90 day inspection was ever conducted. He was near the No. 2 Belt drive when the explosion occurred. During the evacuation, Jamison did not don his SCSR. He indicated that he did not observe any smoke or feel any heat. He stated, "I had it

in my hand. I just was making sure. You know, I had it ready to go.” The records indicate that he had Annual Refresher Training at the Spruce Fork Mine No. 1 on January 28, 2005. The training form indicated, “Hands on CSE.” The records indicate that he had Experienced Miner Training at the Sago Mine on June 27, 2005.

### **Miners on the 1st Left Mantrip**

At the time of the explosion, Denver Anderson, Avington, Carpenter, Grall, Helmick, Hess, Owen Jones, Keith, Perry, Rowan, Ryan, Tenney, and Wamsley were on the 1st Left mantrip at the 1st Left switch. After the explosion, they encountered dust, smoke and other contaminants. Seven of the thirteen miners eventually donned their SCSRs as they evacuated the mine. Records indicated which SCSRs were assigned to twelve of the thirteen miners, and the records for the remaining miner indicated that he was assigned a different SCSR than was recovered. It was not possible to state conclusively which SCSR was carried or used by the miners at the time of the accident. The mine operator’s records indicated that the 90 day inspection was completed for eight of the thirteen SCSRs, including four of the seven miners who had donned their SCSRs. Although records indicated that twelve of the thirteen miners had received training on the SCSR within one year, the remaining miner had received training in December of 2005. The type of training was not indicated on the training form. His training was given the same day the other miners at the Sago Mine received Experienced Miner Training. One miner indicated he had difficulty removing his SCSR from his pouch. One miner indicated he had difficulty opening his unit. All of the seven miners who donned SCSRs reported that the units worked, but three indicated they had some type of difficulty. NIOSH evaluated three of the seven units and indicated the SCSRs activated and produced oxygen.

Denver Anderson - The Spruce Mine inspection records indicated SCSR 83566 was assigned to Denver Anderson. The 90 day inspection occurred on February 14, 2005. Although the unit was manufactured in May of 2001, the Spruce Mine records show it was manufactured in May of 2004. There were no records from the Sago mine indicating which SCSR was assigned to Anderson, or that the 90 day inspection was completed. Anderson donned his SCSR shortly after he exited the 1st Left mantrip, and had no difficulty doing so. Hess assisted Anderson and stated “his rescuer had BlocBond on it and he was having trouble with where it was on his belt, getting it up out of the pouch. So he had the channel locks down in his pouch, too, so I pulled those out and of course, you know, I'm beside him so I kept my hands under it and got it pushed up out.” Anderson put his rescuer on, “because of all the smoke and that.” The unit worked as expected. He continued to use the unit until he got in the mantrip to evacuate the mine. As SCSR 83566 was not recovered, there are no NIOSH

evaluation results available. The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005.

Paul Avington - The Spruce Mine inspection records indicated SCSR 63277 was assigned to Paul Avington. The 90 day inspection occurred on February 14, 2005. It was manufactured in July of 1998. There were no records from the Sago Mine indicating which SCSR was assigned to Avington, or when the 90 day inspection was completed. During the evacuation, Avington did not don his SCSR. He indicated, "I just didn't think I needed it." The records show he had Annual Refresher Training at the Spruce Fork Mine on August 27, 2004. The training form indicated "CSE 100." The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005.

Gary Carpenter - The Spruce Mine inspection records indicated SCSR 75648 was assigned to Gary Carpenter. The 90 day inspection occurred on February 14, 2005. It was manufactured in March of 2000. There were no records from the Sago Mine indicating which SCSR was assigned to Carpenter or whether the 90 day inspection was performed. During the evacuation, Carpenter did not don his SCSR. He stated, "We never really discussed, you know, but there was an explosion because of the air and the debris. It was just kind of obvious." The records show he had Annual Refresher Training at the Spruce Fork Mine on August 20, 2004, and Experienced Miner Training at the Sago Mine on December 8, 2005.

Ron Grall - The mine operator's inspection records indicated that SCSR 92943 was assigned to Grall and that the most recent 90 day inspection was performed on November 17, 2005. The unit was manufactured in May of 2002. During the evacuation, Grall did not don his SCSR. He indicated, "[t]he reason I didn't put mine on is because I didn't smell any smoke. I could smell --- the taste of dust, sulfur taste, but you couldn't see --- couldn't taste no --- smell no smoke or anything so I figured as long as I could breathe, I wasn't putting mine on." He said that training should be held more often, "the self-rescuer, they need to do that more frequently. I mean, because once a year, you kind of forget that stuff." The records show he had Annual Refresher Training at the Spruce Fork Mine on August 21, 2004, and Experienced Miner Training at the Sago Mine on September 16, 2005.

Randall Helmick - The mine operator's inspection records indicated that SCSR 56505 was assigned to Helmick, and that the last 90 day inspection took place on November 15, 2005. The unit was manufactured in September of 1997. During the evacuation, Helmick did not don his SCSR because he was saving it. He stated, "I didn't put mine on because I was still breathing. You know, I didn't feel like I was having any difficulty of breathing. And we didn't know if, you know, we was going to have a second explosion or what." The records show he

had Annual Refresher Training at the Spruce Fork Mine No 1 on April 2, 2004. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005.

Eric Hess - The mine operator's inspection records indicated that SCSR 88170 was assigned to Hess and the 90 day inspection was completed on November 14, 2005. Although the unit was manufactured in December of 2001, the mine operator's records show it was manufactured in December of 2002. After the explosion, he exited the 1st Left mantrip and traveled outby where he checked and found that he did not have fresh air in the primary intake escapeway. He then donned his SCSR. He had no difficulty in donning it, and it worked as expected. He continued to wear the unit until he encountered clear air at approximately 26 Crosscut, No. 4 Belt. SCSR 88170 was not one of the units recovered for evaluation. Therefore, there were no evaluation results available. The records show that Hess had Annual Refresher Training at the Spruce Fork Mine on April 16, 2004. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on October 6, 2004, but this training was received more than a year prior to the date of the accident. While the records indicate that Hess had some type of training at the Sago Mine on December 8, 2005, the type of training was not marked on the 5000-23 form required by MSHA. However, as many other miners received Experienced Miner Training on December 8, 2005, it is likely that this is the type of training that Hess received.

Owen Jones - The mine operator's inspection records indicated that SCSR 92933 was assigned to Jones and that the 90 day inspection was done on November 14, 2005. The unit was manufactured in June of 2002. Jones was the section foreman for the 1st Left crew. During the evacuation, Jones did not don his SCSR. He stated, "I should have, but I didn't." He stated, "my carbon monoxide detector went off immediately after the explosion." Jones went to the doctor the following week due to an odd feeling in his chest. A blood test revealed that he had a "high level of carbon monoxide...." He did not evacuate to the surface with his crew but rather stayed near the phone near 37 Crosscut, No. 4 Belt. He met with Jeffrey Toler, Wilfong, and Schoonover, and they installed ventilation controls up to 57 Crosscut, No. 4 Belt. The records show he had Annual Refresher Training at the Sago Mine on March 18, 2005. The training form indicated, "Hands on SCSR." The records indicate that he had Experienced Miner Training at the Sago Mine on December 8, 2005.

Hoy Keith - The Spruce Mine inspection records indicated SCSR 60035 was assigned to Hoy S. Keith, Jr. The 90 day inspection occurred on February 14, 2005. It was manufactured in January of 1998. There were no records from the Sago Mine indicating which SCSR was assigned to Keith or if the 90 day inspection was completed. Keith donned his SCSR shortly after he exited the 1st

Left mantrip. He indicated "I was just a little bit disoriented whenever it happened" and other miners that already had donned their SCSR assisted him, including Wamsley. Wamsley stated, "I helped him get it on, around his neck, nose clips on, everything. I pulled the thing and it didn't activate." When Wamsley was asked if Keith tried to start the unit manually, he stated, "No. I don't even know if he had enough wind to do that." However, Keith indicated that it worked as expected. Rowan indicated that Keith was having difficulties breathing and he stayed with him, sharing his SCSR with Keith as they evacuated the mine. Rowan said that Keith's SCSR appeared to be working but he could not tell for sure, and that Keith was upset with the situation. Rowan said, "I'm not sure that he actually even had any trouble with his. Like I said, he just kind of --- I know that the bag was out on his and everything like that. I mean, it looked like it was working." Keith indicated he continued to wear the unit until he got to fresh air and entered the mantrip to evacuate the mine. SCSR 60035 was not recovered, therefore there were no NIOSH evaluation results available. The records show that he had Annual Refresher Training at the Spruce Fork Mine No 1 on August 20, 2004, and Experienced Miner Training at the Sago Mine on December 8, 2005.

Arnett Perry - The mine operator's inspection records indicated that SCSR 102138 was assigned to Perry and the unit had a 90 day inspection on November 15, 2005. The manufacture date was January of 2004. He exited the mantrip and did not don it immediately "Because that's all I could remember, one hour. And I thought; well, now I've been told it takes two hours to walk out of here." He traveled outby and got into the intake entry. He then donned his SCSR. Ryan assisted him. Perry said, "I suppose it worked all right. Other than I was trying to breathe too hard and it sucked the bag together." He did not believe that he pulled the oxygen activator tag. Instead, he manually started the unit. "Every little bit, I was taking it (the mouthpiece) out because I wasn't getting enough air it seemed like." Ryan stated, "Got it open, got the bag and everything out, he (Perry) got it in his mouth, put his nose clips on, I activated it, the bag blew wide open. Within a block, the bag collapsed. He couldn't breathe. He had to take it out of his mouth. And I tried to get him to leave it in his mouth and just breathe with what he could get, but he said he couldn't breathe, so he took it off." Perry removed the mouthpiece from his mouth when he arrived at the mantrip. The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 102138 was recovered and was evaluated by NIOSH. The dust shield had some cracks, but the canister was not dented. The damage was not significant. NIOSH established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 20% of the chemicals in the unit

were used. The goggles were attached to the unit.<sup>32</sup> CSE and ATL conducted chemical analyses of the unit. They reported that approximately 29% and 31% of the chemicals in the unit had been depleted, respectively.

Gary Rowan - The mine operator's inspection records indicated that SCSR 59965 was assigned to Rowan and the last 90 day inspection was performed on November 14, 2005. The manufacture date was February of 1998. However, SCSR 59965 was not recovered. MSHA inspection records for the Sago Mine from June of 2004 indicated that SCSR 86537 was assigned to Rowan. The record indicated the unit was manufactured in September of 2003. The manufacture date was September of 2001. There are no records from the Sago Mine indicating that the 90 day inspection was completed for that unit. He exited the mantrip, traveled outby into the intake entry and donned his SCSR. He stated, "I should have put it on as soon as it happened." He did not have any difficulty in donning his SCSR, and it worked as expected. During the evacuation, he assisted Keith and stated, " I took my mouthpiece out and let him take, you know, deep breaths so he could take some air and stuff out of mine and stuff because he said he wasn't sure that his was working or not." He indicated he left his SCSR on until he got outside. The records show that Rowan had Annual Refresher Training at the Sago Mine on March 18, 2005. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 86537 was recovered, and was evaluated by NIOSH. "Gary Rowe" was written on the unit. The dust shield had some cracks but the canister was not dented. The damage was not significant. NIOSH reported that the start-up oxygen was activated, the unit produced oxygen and approximately 10% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 19% and 28% of the chemicals in the unit had been depleted, respectively.

Harley Joe Ryan - The mine operator's inspection records indicated that SCSR 97144 was assigned to Ryan and the last 90 day inspection was done on November 16, 2005. The manufacture date was December of 2003. He exited the mantrip and walked outby where he donned his SCSR. Wamsley assisted him. Ryan stated, "You just couldn't get the tab off. You couldn't get ahold of it for one thing. ....The bottom part of mine, we had to jerk on it two or three times to get it to unseal." He had difficulty with the mouthpiece, "You can't hold something in your mouth if you don't have teeth that's designed for something to hold with your teeth. What they're going to do about that, I don't know. I kept it in my mouth. I had trouble keeping it in, but I kept it in." He further

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<sup>32</sup> The goggles may have been placed there by the evidence teams as they were recovered.

stated, "I just know I was with him, walking with him when mine started getting to the point I couldn't breathe real good with it...But I was going slow enough with Roger that I wasn't asking this thing for more than what I was getting out of it." and "I knowed it was overriding what was left in it. And I would rather breathe what it was giving me than the air that was out there." He indicated he did not remove the unit until he was outside the mine. The records show that Ryan had Annual Refresher Training at the Sago Mine on January 27, 2005. The training form indicated, "Hands on SCSR." The records show that he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 97144 was recovered and evaluated by NIOSH. The dust shield had some cracks but the canister was not dented. The damage was not significant. There was foreign matter in the mouthpiece that appeared to be snuff, but the breathing tube was not obstructed. According to NIOSH, the start-up oxygen was activated, the unit produced oxygen, and approximately 40% to 50% of the chemicals in the unit had been used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 42% and 48% of the chemicals in the unit had been depleted, respectively.

Christopher Tenney - The mine operator's inspection records indicated that SCSR 52409 was assigned to Tenney and the 90 day inspection was completed on November 14, 2005. The manufacture date was June of 1997. During the evacuation, Tenney did not don his SCSR. He stated, "well, actually I wasn't having any trouble breathing and I didn't know what we were going to encounter further out and I don't know what I was thinking, I guess maybe save it in case I needed it at a later point." The records show that Tenney had Annual Refresher Training at the Sago Mine on March 18, 2005. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005.

Anton Wamsley - The mine operator's inspection records indicated that SCSR 88981 was assigned to Wamsley, with the last 90 day inspection occurring on November 17, 2005. The unit was manufactured in November of 2001. He exited the mantrip, traveled outby and found that he did not have clear air in the primary intake escapeway. He donned his SCSR with no difficulty, it worked as expected, and he indicated that he kept it on until he got almost outside. SCSR 88981 was not one of the units recovered for evaluation. Therefore, there were no evaluation results available. The records show that Wamsley had Annual Refresher Training at the Sago Mine on February 25, 2005, and Experienced Miner Training at the Sago Mine on December 8, 2005.

### **Miner Working Near the Mouth of 2nd Left Parallel**

Terry Helms - SCSR 90223 was found with Helms. The Spruce Mine inspection records indicated SCSR 90223 was assigned to Terry Helms and the 90 day

inspection occurred on February 12, 2005. There were no records from the Sago Mine indicating that the 90 day inspection was completed for an SCSR belonging to Terry Helms, but there were records for SCSR 90223. The Sago Mine inspection records indicated that this unit was not assigned to any miner, and that the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 14, 2005. The manufacturing date was December of 2001. Helms did not don his SCSR. The records show he had Annual Refresher Training at the Spruce Fork Mine #1 on April 21, 2005. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on June 27, 2005. SCSR 90223 was recovered. It was evaluated by NIOSH. The dust shield had cracks but the canister was not dented. Some pieces of the dust shield were missing. The damage was significant. "Terry Helms" was written on the unit. It did not pass the ASMD test. The mine operator's inspection records indicated the unit passed the ASMD test on November 14, 2005. It was not possible to state conclusively whether this unit would have passed or failed these required tests prior to the explosion. The SCSR was tested on a breathing simulator. It did not have sufficient start-up oxygen to fill the breathing bag. However, the unit did pass the breathing simulator test when started manually. It operated for 64 minutes before being fully consumed.

### **Miners on 2nd Left Parallel**

At the time of the explosion, Thomas Anderson, Alva Bennett, James Bennett, Groves, Hamner, Jesse Jones, Lewis, McCloy, Martin Toler, Ware, Weaver, and Winans were on the 2nd Left Parallel section. They tried to evacuate and eventually donned their SCSRs. McCloy indicated that Jones, Anderson, Toler, and Groves felt that their units were not functioning. Records from the Sago Mine and the Spruce Mine indicated which SCSRs were assigned to ten of the twelve miners, and the mine operator provided information on the assignment of SCSRs for the remaining two miners. However, it was not possible to state conclusively that the SCSRs were carried and used by the miners to whom they were assigned at the time of the accident. The mine operator's records indicated that the 90 day inspection was completed for six of the twelve SCSRs. The mine records indicate that only one of the four SCSRs that McCloy stated did not function as intended had been inspected within the previous 90 days. The SCSR assigned to one miner was more than 10 years old. Records indicated that all of the twelve miners had received SCSR training within the previous year. All of the twelve SCSRs recovered were evaluated by NIOSH. These evaluations indicated that they all were activated and produced oxygen. The visual observations indicated that eight of the twelve units had depleted approximately 30% or less of the chemicals.



Thomas Anderson – The Spruce Mine inspection records indicated SCSR 92652 was assigned to Tom Anderson and the 90 day inspection occurred on February 14, 2005. There were no records from the Sago Mine indicating any SCSR for Anderson or that the 90 day inspection was completed for SCSR 92652. Although the unit was manufactured in March of 2002, the Spruce Mine inspection records show it was manufactured in March of 2003. This unit was found opened in the barricade, about two feet from the victim. McCloy indicated that Anderson had problems with his SCSR. The records show he had Annual Refresher Training at the Spruce Fork Mine on August 13, 2004, and Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 92652 was recovered. NIOSH evaluations indicated that the goggles were attached to the unit<sup>33</sup>, the dust and heat shield were off of the unit, the dust shield was cracked with pieces missing, the pads were missing on the nose clips, there was a tear on the breathing tube close to the saliva trap, the top bushing was displaced three-quarters of the way down the unit and the bottom bushing was cut and dislodged but in place. The bottom corner of the canister was damaged, there was dirt on the breathing bag and there were possible signs of an inward leak of dirt onto the bag. The damage was significant. NIOSH reported that the start-up oxygen was activated, the unit produced oxygen and approximately 40% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 39% and 48% of the chemicals in the unit had been depleted, respectively.

Alva Bennett – The Spruce Mine inspection records indicated SCSR 89765 was assigned to Alva M. Bennett and the 90 day inspection occurred on February 12, 2005. There were no records from the Sago Mine for any SCSR for Alva Bennett or that the 90 day inspection was completed for SCSR 89765. The unit was manufactured in December of 2001. This unit was found opened in the barricade, about 17 feet from the victim. The records show he had Annual Refresher Training at the Spruce Fork Mine No. 1 on April 21, 2005. The training form indicated, “Hands on SCSR.” The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 89765 was recovered. It was evaluated by NIOSH. The dust shield had cracks but the canister was not dented. The damage was significant. The laboratory also indicated that the mouthpiece plug was tied to the bottom of unit, the neck strap and part of the waist strap were missing, the dust shield was broken and the heat shield was damaged, and the bottom filter showed evidence of mineralization. Mineralization occurs when some of the chemical contained in the breathing bag is dissolved in water and is re-deposited in a fine layer on the bottom of the filter. NIOSH reported that the start-up oxygen was activated, the unit produced

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<sup>33</sup> The goggles may have been placed there by the evidence teams as they were recovered.

oxygen and approximately 25% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 38% and 54% of the chemicals in the unit had been depleted, respectively.

James Bennett – The mine operator indicated that SCSR 56495 was assigned to Bennett. The manufacture date was November of 1997. The Spruce Mine inspection records indicated SCSR 89203 was assigned to Jim Bennett and the 90 day inspection occurred on February 14, 2005. Those records also indicated that SCSR 56495 belongs to another miner. There were no records from the Sago Mine for SCSR 56495 or for any SCSR for Bennett in the 90 day inspection record. SCSR 56495 was found opened in the barricade about 17 feet from the victim. The records show that he had Annual Refresher Training at the Spruce Fork Mine #1 on April 22, 2005, and Experienced Miner Training at the Sago Mine on July 27, 2005 and on December 8, 2005. SCSR 56495 was recovered. NIOSH evaluations indicated the dust shield had some cracks and the canister had some dents, but they were not severe. The damage was not significant. The breathing tube was set but was pliable and open. “Smargo” was written on the unit. There was green paint on the unit. NIOSH’s report indicated that the start-up oxygen was activated, the unit produced oxygen and approximately 25% to 35% of the chemicals in the unit were used.

Jerry Groves – The Spruce Mine inspection records indicated SCSR 57878 was assigned to Jerry Groves and the 90 day inspection occurred on February 14, 2005. There were no records from the Sago Mine for SCSR 57878 or for any SCSR for Jerry Groves in the 90 day inspection period. Although the unit was manufactured in December of 1997, the Spruce Mine inspection records show it was manufactured in February of 1997. SCSR 57878 was found opened in the barricade about 10 feet from the victim. McCloy indicated that Grove’s unit was not functional. He stated that the breathing bag did not inflate when the unit was opened, or when attempts were made to start the unit manually. The records show he had Annual Refresher Training at the Spruce Fork Mine on August 27, 2004. The training form indicated “CSE.” The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 57878 was recovered. NIOSH evaluations indicated that the dust shield had some cracks and the canister had some dents, but they were not significant. The damage was not significant. The laboratory also indicated that the breathing tube was set but was pliable and open, there was a cut in the top canister bushing and a blister on the neck of the breathing bag, the bottom of the canister showed mineralization, and there was paint on the dust shield. NIOSH reported that the start-up oxygen was activated and that the unit produced oxygen, and estimated that approximately 40% to 50% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 48% and 77% of the chemicals in the unit had been depleted, respectively.

George Hamner – The mine operator indicated that SCSR 101868 was assigned to Hamner, but MSHA inspection records from June of 2004 indicated that SCSR 101868 was assigned to another miner. The manufacture date was January of 2004. There were no records from the Sago Mine indicating that the 90 day inspection was completed for SCSR 101868. The mine operator’s inspection records indicated that a different unit, SCSR 101838, was assigned to Hamner and that the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 18, 2005. SCSR 101838 was not recovered. SCSR 101868 was found opened in the barricade about 49 feet from the victim. The records show he had Annual Refresher Training at the Sago Mine on June 24, 2005. The training form indicated, “Hands on SCSR.” The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 101868 was recovered. NIOSH evaluations indicated the dust shield had some cracks and the canister was dented. The damage was not significant. “Walker” was written on the unit. NIOSH indicated that the start-up oxygen was activated, the unit produced oxygen and approximately 25% of the chemicals in the unit were used. CSE conducted a chemical analysis of the unit. It reported that approximately 31% of the chemicals in the unit had been depleted.

Jesse Jones – The mine operator’s inspection records indicated that SCSR 46433 was assigned to Jones and that the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 17, 2005. Although the unit was manufactured in August of 1995, the mine operator’s inspection records show it was manufactured in August of 1996. The unit should have been taken out of service on its 10 year anniversary, almost five months prior to the accident. This unit was found opened in the barricade about 27 feet away from the victim. McCloy indicated that Jones had problems with the SCSR. The mine records show that Jones had Annual Refresher Training at the Sago Mine on March 18, 2005. The training form indicated, “Hands on SCSR.” The records indicate that he had Experienced Miner Training at the Sago Mine on March 22, 2004. The training form indicated, “Hands on SCSR.” SCSR 46433 was recovered. NIOSH evaluations indicated the dust shield had cracks but the canister was not dented. The damage was significant. The unit would not pass the visual exam because it was past its service date. The breathing tube was set but pliable and open, the heat shield was loaded with dirt and there was a stain on the breathing bag at the lanyard tie point. NIOSH reported that the start-up oxygen was activated, the unit produced oxygen and approximately 10% to 20% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 41% and 50% of the chemicals in the unit had been depleted, respectively.

David Lewis – The mine operator’s inspection records indicated that SCSR 101831 was assigned to Lewis and the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 18, 2005. The

manufacture date was January of 2004. SCSR 101831 was found opened in the barricade, about 10 feet from the victim. The records show he had Annual Refresher Training at the Sago Mine on April 22, 2005. The training form indicated "Hands on SCSR." The mine records show he had training at the Sago Mine on December 8, 2005, but the type of training is not marked on the 5000-23 form. However, as many other miners received Experienced Miner Training on December 8, 2005, it is likely that this is the type of training that Lewis received. The mine records show he had Experienced Miner Training at the Sago Mine on December 15, 2005. SCSR 101831 was recovered. NIOSH evaluations indicated the dust shield was cracked and the canister was dented. The damage was not significant. NIOSH indicated that the start-up oxygen was activated, that the unit produced oxygen and that approximately 10% to 20% of the chemicals in the unit were used. CSE conducted a chemical analysis of the unit, and reported that approximately 25% of the chemicals in the unit had been depleted.

Randal L. McCloy Jr. - The mine operator's inspection records indicated that SCSR 106154 was assigned to McCloy and the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 18, 2005. The manufacture date was July of 2004. SCSR 106154 was found opened in the barricade, about 21 feet from where he was found. McCloy stated that his unit "worked fine." The records show he had Annual Refresher Training at the Sago Mine on August 19, 2005, and Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 106154 was recovered. NIOSH evaluations indicated the dust shield had no cracks and the canister was not dented. The damage was not significant. There was green paint on the breathing tube. The laboratory also indicated that the lenses on the goggles were displaced and the relief valve was sticking closed. Although the sticking relief valve could have eventually affected the performance, it was not likely to affect the initial performance. It may have occurred after the unit was used and may not conclusively reflect the condition of the unit prior to the explosion. NIOSH reported that the start-up oxygen was activated, the unit produced oxygen, and approximately 20 to 25% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit, and reported that approximately 28% and 29% of the chemicals in the unit had been depleted, respectively.

Martin Toler Jr. - The Spruce Mine inspection records indicated SCSR 57604 was assigned to Martin Toler and the 90 day inspection occurred on February 14, 2005. There were no records from the Sago Mine indicating any SCSR for Martin Toler or that the 90 day inspection was completed for SCSR 57604. There were also other records from the Sago Mine indicating that SCSR 106022 was assigned to "Toler JR" and that the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 17, 2005. The manufacture date was December of 1997. SCSR 57604 was found opened in the barricade, about 32 feet from the victim. McCloy indicated that Martin Toler had problems with the

SCSR. Martin Toler may have been confronted with a situation in which the miners felt they did not have enough working SCSRs to escape through the heavy smoke. McCloy stated that Toler said "this ain't safe like this. Let's go back to the section." SCSR 106022 was not recovered. The records show he had Annual Refresher Training at the Spruce Fork Mine on August 27, 2005 and Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 57604 was recovered. NIOSH evaluations indicated the dust shield had some cracks but the canister was not dented. The damage was marginal. Some pieces of the dust shield were missing, the breathing tube was set but was pliable and open, and there was a stain on the breathing bag at the lanyard tie point. NIOSH indicated that the start-up oxygen was activated, the unit produced oxygen, and approximately 10% to 15% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 21% and 27% of the chemicals in the unit had been depleted, respectively.

Fred Ware - The mine operator's inspection records indicated that SCSR 56880 was assigned to Ware and the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 17, 2005. The manufacture date was October of 1997. SCSR 56880 was found opened in the barricade near the victim. The records show that Ware had Annual Refresher Training at the Sago Mine on March 25, 2005. The training form indicated, "Hands on SCSR." The records show he had other training at the Sago Mine on December 8, 2005. The type of training was not marked on the 5000-23 form. However, as many other miners received Experienced Miner Training on December 8, 2005, it is likely that this is the type of training that Ware received. SCSR 56880 was recovered. NIOSH evaluations indicated the dust shield had some cracks but the canister was not dented. The damage was marginal. There was tape around the relief valve, and the breathing tube was set but was pliable and open. "Fred Ware Jr." was written on the unit. NIOSH evaluations showed that the start-up oxygen was activated, the unit produced oxygen and approximately 10% to 20% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit, and reported that approximately 39% and 41% of the chemicals in the unit had been depleted, respectively.

Jackie Weaver - The mine operator's inspection records indicated that he was assigned SCSR 57334. There were records indicating the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 16, 2005. The manufacture date was December of 1997. SCSR 57334 was found opened in the barricade, about 19 feet from the victim. The records show that Weaver had Annual Refresher Training at the Sago Mine on October 14, 2005. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 57334 was recovered. NIOSH evaluations indicated the dust shield had cracks but the canister had no dents. The damage was significant. The breathing tube was set

but was pliable and open, the tag was missing on the lanyard for the firing lever, the dust shield was broken and cracked and the heat shield was loaded with dirt. There was rust at the relief valve lanyard attachment point to the breathing bag but the lanyard attachment was still solid. NIOSH reported that the start-up oxygen was activated, the unit produced oxygen and approximately 30% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 39% and 34% of the chemicals in the unit had been depleted, respectively.

Marshall Winans – The mine operator’s inspection records indicated that he was assigned SCSR 52478. There were records indicating the 90 day inspection was completed in a timely manner and that the last inspection occurred on November 14, 2005. The manufacture date was June of 1997. SCSR 52478 was found opened in the barricade about 27 feet from the victim. The records show that he had Annual Refresher Training at the Spruce Fork Mine on August 13, 2004 and Experienced Miner Training at the Sago Mine on December 8, 2005. SCSR 52478 was recovered. NIOSH evaluations indicated the dust and heat shields were missing, and the canister had dents. The damage was significant. The breathing tube was set but was pliable and open, the upper bushing was missing, there was staining on the breathing bag at the lanyard tie point, the nose clips were stuck together, and there was evidence of moisture in the bottom filter. NIOSH reported the start-up oxygen was activated, the unit produced oxygen and 50% to 60% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 72% and 87% of the chemicals in the unit had been depleted, respectively.

### **Miners Attempting Rescue Effort**

After the explosion, Hofer, Schoonover, Jeffrey Toler, and Wilfong entered the mine. They did not use their SCSRs. Records indicated which SCSRs were assigned to each of the four miners. However, it was not possible to state conclusively that an SCSR was carried by the miner to whom it was assigned at the time of the accident. The mine operator’s records indicated that the 90 day inspection was completed for three of the four SCSRs. The records indicated three of the four miners had received training on the SCSR within the past year.

Vernon Hofer – The mine operator’s inspection records indicated he was assigned SCSR 63274. There were records indicating that the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 17, 2005. The manufacture date was October of 1998. Hofer also entered the mine after the explosion. He did not don his SCSR. He stated, “I wasn’t having trouble breathing. I wasn’t --- didn't notice any adverse effects from the conditions that we were working in....” The records show he had Annual Refresher Training at the Sago Mine on February 28, 2005. The training

form indicated, "Hands on SCSR." The records indicate that he had Experienced Miner Training at the Sago Mine on February 4, 2004.

James Allen Schoonover- The mine operator's inspection records indicated he was assigned SCSR 104889. There were records indicating the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 17, 2005. The manufacture date was June of 2004. Schoonover entered the mine with Toler after the explosion. He stated, "We would repair whatever, whatever stopping it was and the detector, of course, it would go down, it wouldn't have any alarm. It would advance. You know, you could --- your detector would go off again, get a piece of curtain hung, and we would bring the fresh air behind us." He did not don his SCSR. He stated, "Because I felt there was no need to at that time." Schoonover was responsible for the training at the mine. The records show he had Annual Refresher Training at the Spruce Fork Mine on August 9, 2002 and Experienced Miner Training at the Sago Mine on January 12, 2004. The records indicated that it had been over a year since Schoonover received SCSR Training.

Jeffrey Toler - The mine operator's inspection records indicated he was assigned SCSR 104831. There are records indicating that the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 14, 2005. The manufacture date was June of 2004. Jeffrey Toler entered the mine after the explosion. Along with the others, he repaired damaged ventilation controls to re-establish airflow. He did not don his SCSR. "With us keeping fresh air with us, I never felt like we were in a concentration of CO that I felt that I needed it," he stated. When he was in the track entry at 49 Crosscut, No. 4 Belt, he stated, "I think it (the concentration of carbon monoxide) was in excess of 700 parts per million at that point." The records show he had Experienced Miner Training at the Sago Mine on August 2, 2005.

Denver Wilfong - The Spruce Mine inspection records indicated SCSR 55656 was assigned to Denver Wilfong and was manufactured in September of 1997. There were no records from the Sago Mine indicating SCSR 55656 was assigned to Wilfong or if the 90 day inspection was completed for that unit. Wilfong entered the mine after the explosion as well, but did not don his SCSR. He stated, "I was saving it 'til I needed it, I guess." The records show he had Annual Refresher Training at the Spruce Fork Mine on August 22, 2003. The training form indicated, "Hands on SCSR." The records show he had Experienced Miner Training at the Sago Mine on December 6, 2005.

## Other SCSRs Recovered and Evaluated

SCSRs 106603 and 107966 were recovered and believed to belong to miners on the 1st Left mantrip. There were no records from the Sago Mine for SCSR 106603

SCSRs 109419, 57517, 106615, 109482 and 109455 were found in the barricade. SCSR 101106 was found on the 2nd Left Parallel Section. They were opened and activated on January 3 - 4, 2006. These units were believed to be opened during the rescue of McCloy. According to testimony, they were only used for a brief period of time. They were recovered by the investigation team and stored in plastic bags until they were evaluated on March 27 - 31, 2006. The visual observations indicated that between 5% and 10% of the chemicals in the units were used. This shows that any change that might have occurred in the chemical beds of the units as a result of either the units' exposure to the mine atmosphere until they were recovered, the storage procedure used or the length of time that elapsed between recovery and evaluation, was minimal. This conclusion is further supported by the results of the laboratory test conducted in 2006.

SCSR 106603 was recovered and is believed to belong to one of the miners on the 1st Left mantrip. However, the Spruce Mine inspection records indicated SCSR 106603 was assigned to another miner and the 90 day inspection occurred on February 12, 2005. There were no records from the Sago Mine for SCSR 106603. The manufacture date was in August of 2004. SCSR 106603 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 20% to 25% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 23% and 46% of the chemicals in the unit had been depleted, respectively.

SCSR 107966 was recovered and is believed to belong to one of the miners on the 1st Left mantrip. The mine operator's inspection records indicated that SCSR 107966 was not assigned to any miner and the 90 day inspection was completed in a timely manner, with the last inspection occurring on November 16, 2005. The manufacture date was November of 2004. SCSR 107966 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. "Walker" was written on the unit. There was evidence of moisture on the bottom filter. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 80% to 90% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 48% and 63% of the chemicals in the unit had been depleted, respectively.



SCSR 109419 was recovered in the barricade and is believed to have been opened during the rescue effort. There were no records from the Sago Mine for SCSR 109419. The manufacture date was in October of 2004. SCSR 109419 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 5% to 10% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 11% and 14% of the chemicals in the unit had been depleted, respectively.

SCSR 57517 was recovered in the barricade and is believed to have been opened during the rescue effort. The Spruce Mine inspection records indicated SCSR 57517 was assigned to another miner not on the 2nd Left Parallel crew and the 90 day inspection occurred on February 14, 2005. There were no records from the Sago Mine for SCSR 57517. The manufacture date was December of 1997. SCSR 57517 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. NIOSH indicated the breathing tube was set but was pliable and open. The cap was missing from the relief valve. The breathing bag had an impression from the goggles or a stain on the bag. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 5% to 10% of the chemicals in the unit were used. CSE and ATL conducted chemical analyses of the unit. They reported that approximately 20% and 34% of the chemicals in the unit had been depleted, respectively.

SCSR 106615 was recovered in the barricade and is believed to have been opened during the rescue effort. The mine operator's inspection records indicated SCSR 106615 was assigned to another miner not on the 2nd Left Parallel crew and the 90 day inspection occurred on November 16, 2005. The manufacture date was August of 2004. SCSR 106615 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. NIOSH indicated that there was mineralization on the bottom filter. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 10% of the chemicals in the unit were used.

SCSR 109482 was recovered in the barricade and is believed to have been opened during the rescue effort. There were no records from the Sago Mine for SCSR 109482. The manufacture date was in October of 2004. SCSR 109482 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 5% to 10% of the chemicals in the unit were used.

SCSR 109455 was recovered in the barricade and is believed to have been opened during the rescue effort. The mine operator's inspection records indicated SCSR 109455 was not assigned to any miner and there was no record of the 90 day inspection. The manufacture date was in October of 2004. SCSR 109482 was evaluated by NIOSH. The dust shield was dented and the canister was dented. Any damage was marginal. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 10% of the chemicals in the unit were used. CSE conducted chemical analyses of the unit. They reported that approximately 21% of the chemicals in the unit had been depleted.

SCSR 101106 was recovered on the 2nd Left Parallel section and is believed to have been opened during the rescue effort. The Spruce Mine inspection records indicated SCSR 101106 was assigned to a miner not on the 2nd Left Parallel crew, and that the 90 day inspection occurred on February 14, 2005. There were no records from the Sago Mine for SCSR 101106. The manufacture date was May of 2004. SCSR 101106 was evaluated by NIOSH. The dust shield had no cracks and the canister was not dented. Any damage was not significant. NIOSH evaluations established that the start-up oxygen was activated, that the unit produced oxygen, and that approximately 10% of the chemicals in the unit were used.

Table 7 is a summary of the SCSRs that were assigned to the miners who were underground at the time of the explosion, were assigned to the miners who traveled underground during the rescue attempt, and that were used by the mine rescue team assisting McCloy.

**Table 7 – Summary of Information on the SCSRs at the Sago Mine**

Miner	Location	Serial No.	Date of SCSR Training	Was Unit Donned	90 Day Inspection Record at Sago	Evidence of Oxygen Production	NIOSH Visual % Used	CSE % Used	ATL % Used
John N. Boni	Outby	106186	10/07/05 <sup>1</sup>	No	11/14/05	-	-	-	-
John P. Boni	Outby	100991	12/29/04 <sup>2</sup>	No	11/16/05	-	-	-	-
James Jamison	Outby	91947	06/27/05	No	None	-	-	-	-
Denver Anderson	1st Left	83566	12/08/05	Yes	None	na	na	na	na
Paul Avington	1st Left	63227	12/08/05	No	None	-	-	-	-
Gary Carpenter	1st Left	75648	12/08/05	No	None	-	-	-	-
Ronald Grall	1st Left	92943	09/16/05	No	11/17/05	-	-	-	-
Randall Helmick	1st Left	56505	12/08/05	No	11/15/05	-	-	-	-
Eric Hess	1st Left	88170	12/08/05 <sup>3</sup>	Yes	11/14/05	na	na	na	na
Owen Jones	1st Left	92933	12/08/05	No	11/14/05	-	-	-	-
Hoy Keith	1st Left	60035	12/08/05	Yes	None	na	na	na	na
Arnett Perry	1st Left	102138	12/08/05	Yes	11/15/05	Yes	20	29	31
Gary Rowan	1st Left	86537	12/08/05	Yes	None	Yes	10	19	28
Harley Ryan	1st Left	97144	12/08/05	Yes	11/16/05	Yes	40 - 50	42	48
Christopher Tenney	1st Left	52409	12/08/05	No	11/14/05	-	-	-	-
Anton Wamsley	1st Left	88981	12/08/05	Yes	11/17/05	na	na	na	na
Terry Helms	2nd Left	90223	06/27/05	No	11/14/05	-	-	-	-
Thomas Anderson*	Barricade	92652	12/08/05	Yes	None	Yes	40	39	48
Alva Bennett	Barricade	89765	12/08/05	Yes	None	Yes	25	38	54
James Bennett	Barricade	56495	12/08/05	Yes	None	Yes	25-35	-	-
Jerry Groves*	Barricade	57878	12/08/05	Yes	None	Yes	40-50	48	77
George Hamner	Barricade	101868	12/08/05	Yes	None	Yes	25	31	-
Jesse Jones*	Barricade	46433	03/18/05	Yes	11/17/05	Yes	10-20	41	50
David Lewis	Barricade	101831	04/22/05	Yes	11/18/05	Yes	10-20	25	-
Randal McCloy Jr.	Barricade	106154	12/08/05	Yes	11/18/05	Yes	20-25	28	29
Martin Toler Jr.*	Barricade	57604	12/08/05	Yes	None	Yes	10-15	21	27
Fred Ware	Barricade	56880	3/25/05	Yes	11/17/05	Yes	10-20	39	41
Jackie Weaver	Barricade	57334	12/08/05	Yes	11/16/05	Yes	30	39	34
Marshall Winans	Barricade	52478	12/08/05	Yes	11/14/05	Yes	50-60	72	87
Vernon Hofer	Rescue	63274	02/28/05	No	11/17/05	-	-	-	-
James Schoonover	Rescue	104889	01/12/04	No	11/17/05	-	-	-	-
Jeffrey Toler	Rescue	104831	08/02/05	No	11/14/05	-	-	-	-
Denver Wilfong	Rescue	55656	12/06/05	No	None	-	-	-	-
Other	1st Left	106603	-	Yes	None	Yes	20-25	23	46
Other	1st Left	107966	-	Yes	11/16/05	Yes	80-90	48	63
Other	Barricade	109419	-	Yes	None	Yes	5-10	11	14
Other	Barricade	57517	-	Yes	None	Yes	5-10	20	34
Other	Barricade	106615	-	Yes	11/16/05	Yes	10	-	-
Other	Barricade	109482	-	Yes	None	Yes	5-10	-	-
Other	Barricade	109455	-	Yes	None	Yes	10	21	-
Other	2nd Left	101106	-	Yes	None	Yes	10	-	-

na - SCSR was not available or unable to determine the user

\* - Miners identified by McCloy as having difficulties with their SCSRs

<sup>1</sup> - Did not participate in training but filled out the form

<sup>2</sup> - Did not don the unit during training, training on 07/05/05 by a person not listed as an approved trainer

<sup>3</sup> - Box on training form not marked

## Mine Ventilation Plan

The Ventilation Plan in effect at the time of the explosion addressed specific ventilation requirements. MSHA approved the plan, which included a number of addendums, on May 5, 2005. Six-month reviews were conducted as required. MSHA completed the last six-month review prior to the accident on October 25, 2005.

The plan required that when a Joy 14CM15 continuous mining machine was used and coal was cut, mined or loaded, and the scrubber was on, a minimum of 6,000 cfm and a maximum of 9,000 cfm of air was required at the inby end of the line curtain. When the scrubber was not running, a minimum of 6,000 cfm was required at the inby end of the line curtain. The line curtain was required to be within 40 feet of the point of deepest penetration with blowing face ventilation. When the continuous mining machine was equipped with a scrubber but it was not used, the line curtain was required to be maintained to within 20 feet of the area of deepest penetration with exhaust ventilation. When an Eimco 2810-2 continuous mining machine was used with the scrubber on, a minimum of 6,000 cfm and a maximum of 8,000 cfm of air were required at the inby end of the line curtain. When the continuous mining machine was in the working place with the scrubber off, a minimum of 6,000 cfm was required. When the Joy 14CM15 or the Eimco 2810-2 was not equipped with a scrubber, the plan required a minimum of 5,880 cfm of air at the inby end of the line curtain, or a minimum of 60 fpm mean entry air velocity, whichever was greater. The line curtain was to be maintained within 20 feet of the area of deepest penetration with exhaust ventilation when the machines were not equipped with a scrubber. During roof bolting, the line curtain was required to be maintained to the second full row of roof bolts outby the face and was advanced until the curtain was within 10 feet of the face. A minimum of 3,500 cfm of air was required while the roof bolter was in operation. A minimum of 9,000 cfm was required in the last open crosscut of each split.

The mine used an AMS as the automatic fire warning system required by Section 75.1103. The plan addressed the type of system, capabilities of the system, air velocity along the belt entry, type of activation signals, inspections, examinations, testing and procedures to follow when the system or a portion of the system became inoperative.

On September 28, 2005, MSHA approved a supplement to the plan for a test area of about 300 feet in length, which detailed the ventilation and evaluation of the 2nd Left Mains during and after mining the lower bench of the Middle Kittanning Coal Seam (bottom mining). This bottom mining was to be completed while retreating out of the 2nd Left Mains area. The mine operator was to install seals after completion of the bottom mining.

On October 4, 2005, MSHA approved a supplement to the plan to extend the test area in 2nd Left Mains for mining the lower bench of the Middle Kittanning Coal Seam and for the ventilation and evaluation of the area. The area covered by the supplement was the remainder of 2nd Left Mains and a portion of 2 North Mains extending from the face to a point about one crosscut outby the entrance to 2nd Left Mains. This plan also contained additional safety precautions to further protect persons while bottom mining.

Bottom mining was conducted in some areas of the mine to recover additional coal reserves in the lower bench of the Middle Kittanning Coal Seam that was separated from the upper bench by a layer of rock. Normal mining height during initial development averaged seven feet in the 2nd Left Mains and 2 North Mains. After bottom mining was conducted, the mining height ranged from about 10 to 20 feet. Development was completed in a section before any bottom mining could begin. The belt loading point and equipment were moved outby. A new belt loading point was established and bottom mining commenced at an outby point and moved inby. The continuous mining machine operator commenced mining by cutting a ramp down to the desired depth and continued inby to a pre-determined stopping point. Bottom mining was only conducted in entries. Crosscuts were not bottom mined. Roof support installation was not necessary since the roof had been supported during initial development. To provide some protection against overhanging ribs, the mining plan did not permit bottom mining wider than the development mining. Once the mining was completed in all designated entries for that setup, the belt loading point and equipment were once again moved outby and the process repeated. Once an area was completed, no person was permitted in the area. This would eliminate exposure of persons to the heightened coal ribs. This process continued progressively outby until the designated area to be bottom mined was completed.

Two additional supplements were submitted, and then approved on October 21, 2005 and December 19, 2005 for bottom mining in the A-1 and A-2 Panels off 1st Left. These approved supplements were similar to the approved plan for the 2nd Left Mains and 2 North Mains areas. Appendix J contains the four bottom mining supplements to the ventilation plan.

The ventilation plan contained a set of guidelines for the installation of pre-loaded solid concrete block (Packsetter) seals. MSHA also approved supplements to the plan providing for non-hitched Omega Block seals. These supplements outlined the location and the procedures for installation and ventilation of the seals during and after construction. MSHA approved two supplements on October 24, 2005. The first supplement contained procedures for installation of a 40 inch thick, up to 8 foot high and up to 20 foot wide Omega Block seal. The second supplement described the sequence of constructing seals

for the 2 North Mains area and making air changes. The first change was to show ventilation during construction of the seals and the second was to show the final ventilation after completion of the seals. MSHA approved the third supplement on December 8, 2005. This supplement contained procedures for the installation of the three different configurations of non-hitched Omega Block seals. The first was again a 40 inch thick, up to 8 foot high and up to 20 foot wide seal. The second was a 40 inch thick, up to 10 foot high and up to 20 foot wide seal. The third was a 40 inch thick, up to 12 foot high and up to 20 foot wide seal. The three configurations were submitted and approved in preparation for sealing the A1 and A2 Panels off 1st Left, where the entry exceeded 8 feet in height. Appendix K contains the three supplements to the ventilation plan concerning Omega Seals.

### Mine Ventilation

The mine was ventilated with a blowing ventilation system. The drift openings were numbered from left to right facing inby. Airflow entered the mine through the No. 5 Drift Opening and exited through No. 1 and the three other drift openings, which consisted of a track, conveyor belt and one other common opening. According to the mine record books, the total quantity of intake air entering the mine through the blowing fan at the No. 5 Drift Opening was

146,566 cfm on December 28, 2005. The total quantity of return air exiting the mine through the No. 1 Drift Opening was 101,088 cfm. The remaining 45,478 cfm would have exited the mine through the Nos. 2, 3 and 4 Drift Openings. The blowing fan was an 8 foot diameter, Joy Model Number M96-50 fan, with a blade setting of 8 degrees and operating at about 1.9 inches of water gauge. Figure 12 is a copy of the chart which was on the fan pressure recorder when the explosion occurred. Although the fan chart shows a pressure spike about 6:00 a.m., the explosion occurred about 6:26 a.m. This indicates that the fan chart was not correctly aligned on the pressure recorder to correspond with actual time.

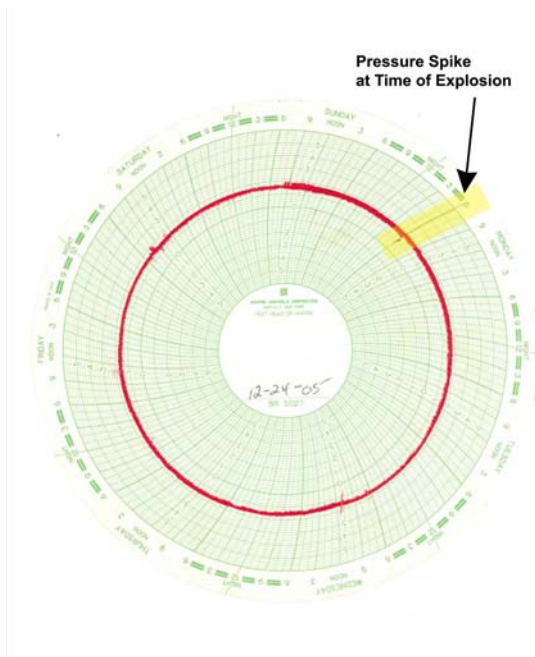


Figure 12 - Fan Chart

## **Development Sections**

The 1st Left and 2nd Left Parallel were developed with eight entries. The sections were ventilated with a single split of air. The entries were numbered from left to right facing inby. The Nos. 7 and 8 entries on the right side of the section served as intake air courses. The Nos. 1 and 2 entries on the left side of the section served as return air courses. The No. 5 entry was the track entry, the No. 4 entry was the conveyor belt entry and the Nos. 3 and 6 entries were common with the belt and track. The sections did not use belt air at the face and the airflow in the Nos. 3, 4, 5 and 6 entries was in an outby direction. The preshift examination record books for the 1st Left and 2nd Left Parallel sections on the day of the accident indicated that the quantity of air measured in the last open crosscut was 14,510 and 11,241 cfm, respectively.

## **Ventilation of Seals**

Two sets of mine ventilation seals were installed to separate worked-out portions of the mine from the active areas. The seals were located across 1 NE Mains and 2 North Mains. The 1 NE Mains seals were ventilated with return air. The 2 North Mains seals were ventilated with intake air that was directed across the seals and over a set of overcasts to the return air course at the mouth of the active 2nd Left Parallel section. Neither the 1st Left nor the 2nd Left Parallel sections were being ventilated with air that passed these seals.

## **Methane Ignitions**

There had been one methane ignition reported at the mine since its opening. The ignition occurred on February 8, 2001. At that time the mine was known as Spruce No. 2 and owned by BJM Coal Company. A section foreman and four miners were preparing to install a tunnel liner into the face area of the No. 5 entry of the 1 NE Mains. In order to install a tunnel liner, a crossbar suspended by three roof bolts about 10 feet outby the face of the No. 5 entry had to be removed. The miners used an oxygen/acetylene cutting torch to cut off the roof bolts holding the crossbar. After the section foreman had completed cutting two of the roof bolts, he raised the cutting torch toward the third roof bolt and ignited methane. The flame extinguished itself, but not before causing first and second degree burns to the four miners. The mine operator later sealed off the 1 NE Mains using preloaded solid concrete block "Packsetter" seals.

## **Methane Liberation**

During each MSHA quarterly inspection of the mine, inspectors collected an air sample in the No. 1 Drift Opening (return air course) to determine the daily methane liberation. To assist in that determination, the air quantity at the

sampled location was determined. The air sample was sent to MSHA's Mount Hope, West Virginia Laboratory to be analyzed. The lab determined the amount of methane in the sample and calculated the quantity of methane liberated from the mine in cubic feet per day. The analysis of the last four quarterly collected air samples is shown in Table 8.

**Table 8 - Air Sample Results**

<b>Date</b>	<b>Methane (%)</b>	<b>Quantity (cfm)</b>	<b>Liberation (cfd)</b>
January 10, 2005	0.09	53,074	68,784
April 29, 2005	0.07	94,446	95,202
July 18, 2005	0.09	83,136	107,744
October 5, 2005	0.10	62,901	90,577

A ventilation survey was conducted on March 1-2, 2006 as part of the accident investigation. Air samples were collected at the drift openings which were out-gassing mine air during the study. The analysis of those samples indicated that the mine liberated 92,460 cfd of methane.

Two methane studies were conducted in the area previously sealed in by the 2 North Mains seals, on February 7-9, 2006 and March 2-3, 2006. Both studies were conducted by collecting information in the mine and from the Nos. 5 and 7 boreholes located in the previously sealed area. Information collected included air samples, air velocities, air temperatures, air pressures, borehole diameters and regulator opening dimensions. This information was used to calculate the methane liberation from the area. The results from the February and March studies indicated that the previously sealed area liberated about 13,220 cfd and 12,090 cfd of methane, respectively.

### **Methane in the Sealed Area**

Methane has a specific gravity of 0.55 and is lighter than air. It is only explosive in methane-air mixtures that range from 5% to 15%. Methane-air mixtures above or below these concentrations will not burn or become involved in an explosion. Generally, methane enters the mine in concentrations in excess of 80% and is diluted by the ventilation current. After the seals were completed, the atmosphere behind the seals was stagnant. Methane entering the area would have the tendency to form layers, with higher concentrations near the mine roof. Additionally, it cannot be assumed that methane would have been liberated equally in each entry or crosscut or from the roof, ribs, or floor. It is likely that the average concentration in the entries would differ throughout the sealed area based on the liberation in each entry.



The results of the methane liberation studies were used to evaluate the volume of methane in the sealed area prior to the explosion. The rate of decay of the methane liberation was considered to be linear. Based on the studies and the assumptions, the methane liberation on December 11, 2005, the day the area was sealed, was approximately 16,350 cfd and on January 2, the day of the explosion, was approximately 15,220 cfd. The average liberation rate for the 22 days that the area was sealed was approximately 15,790 cfd. Therefore, the volume of methane in the sealed area just prior to the explosion was approximately 347,300 cubic feet.

The mine operator provided information to MSHA indicating that the total open volume behind the seals just prior to the explosion was about 2,938,156 cubic feet. Based on this calculation, the volume of methane in the sealed area of 347,300 cubic feet indicates an average homogeneous methane concentration of over 11%. However, it is not likely that a homogenous mixture of 11% was present throughout the sealed area at the time of the explosion.

After the explosion, the volume of air and the concentration of gases exiting the mine through the return drift opening and at the boreholes were monitored. Initially, the methane concentrations at these locations were elevated. Concentrations eventually declined and stabilized to a background level. The volume of methane in the air that exited the mine through the return drift opening and the boreholes that was greater than the background level was calculated. This volume was considered to be excess methane that was in the sealed area prior to the explosion and which was not consumed by the explosion. This excess volume of methane was determined to be approximately 205,500 cubic feet. Since this volume was not involved in the explosion, it was likely in concentrations less than 5% or greater than 15%. Calculations indicate that 141,800 cubic feet of methane (347,300 - 205,500) was consumed by the explosion or ventilated from the mine through another means. This information further supports the conclusion that a homogeneous explosive methane/air mixture did not exist in the sealed area prior to the explosion.

### **Ventilation Survey and Computer Simulations**

Investigators obtained information pertaining to the mine ventilation system from a variety of sources, including mine records, fan charts, mine rescue team maps, mine recovery team maps, underground investigation findings, and interviews and discussions. In addition, they conducted a ventilation survey on March 1-2, 2006, after the mine operator reconstructed the ventilation system to a production-ready configuration.

The ventilation survey consisted of collecting and recording measurements of air velocities, mine entry heights and widths, and air pressures at predetermined

locations throughout the mine. Those locations included but were not limited to air splits, regulators, and the fan. The ventilation survey determined that very small air pressure differentials induced airflow. These pressure differentials were so small, they were often beyond the ability of the instruments being used to accurately measure, thereby making aircourse resistance calculation extremely difficult.

The airflow measurements were balanced so that a computer program could use the data. The entry resistance data was normalized for any given aircourse characteristic. The typical ventilation program data would include airway resistance, airway area, airway length, pressure drop and air quantities. This data would allow the program to make calculations of the ventilation network using the Hardy Cross method. The program may be used to generate tabulated reports, graphs of fan curves and fan operating points, and network distribution diagrams showing pressure drops, resistance, and airflow distribution. However, the program was not written to permit calculations to the degree needed when dealing with air course pressure differentials as small as one-thousandth of an inch of water.

When the ventilation system was reconstructed, it did not replicate the system as it existed on the morning of the accident, prior to the explosion. Differences in the ventilation system included the ventilation of the previously sealed area, the addition of a second bank of overcasts at 1st Left, and the elimination of a set of overcasts at the mouth of 2nd Left Parallel.

In order to replicate the ventilation system, MSHA developed computer simulations to depict the pre- and post-explosion ventilation. However, due to very small pressure differentials of various aircourses throughout the mine, the pre- and post-simulations depicting aircourse patterns and air quantities should be used for demonstrative purposes only.

The simulation depicts the mine ventilation system prior to the explosion, as shown on a map in Appendix L. This illustrates airflow direction and quantities, and ventilating pressures. The results were compared to the information obtained from the sources listed above to verify their accuracy. The simulation indicates that the air quantity delivered on the 1st Left section was 43,300 cfm and on the 2nd Left Parallel section was 46,900 cfm. The simulation indicates the fan would be blowing approximately 172,300 cfm of air into the mine at a fan pressure of 1.85 inches water gauge.

MSHA also developed two post-explosion computer simulations of the ventilation system of the mine after the explosion. The simulation depicting the mine's ventilation system after the explosion with the ventilation controls damaged is shown on a map in Appendix M. This simulation shows that the

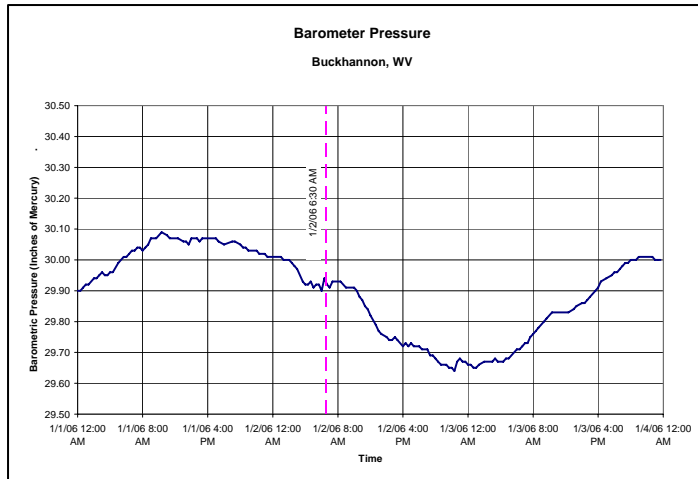
outby damage to the overcast and stoppings at 2 Right and the stopping at 32 Crosscut, No. 4 Belt, decreased the available quantity of intake air moving inby 32 Crosscut, No. 4 Belt from a pre-explosion quantity of 118,400 cfm to 53,000 cfm. The model shows that the damage to the ventilation controls inby 42 Crosscut, No. 4 Belt created major ventilation short circuits, thereby limiting any mechanically induced ventilation inby 49 Crosscut, No. 4 Belt. The model also shows there was no mechanically induced airflow to the mouth of the 2nd Left Parallel.

The second post-explosion simulation is shown on a map in Appendix N and depicts the placement of curtains hung by mine management during their attempt to reach the 2nd Left Parallel crew. Controls include the curtain installed between the intake and track to 57 Crosscut, No. 4 Belt and the curtain hung at the 2 Right overcast. The model indicates repairs to the ventilation controls outby 57 Crosscut, No. 4 Belt created mechanically induced ventilation to 57 Crosscut, No. 4 Belt. The model also indicated that there was mechanically induced airflow to the mouth of the 2nd Left Parallel. Although the simulations indicate that the repairs to the ventilation controls may have had an impact on the atmosphere in the 2nd Left Parallel, the extent of that impact or its affect on the 2nd Left Parallel miners could not be determined.

### **Barometric Pressure**

Changes in barometric pressure can cause the expansion and contraction of accumulated gases within unventilated (sealed) and poorly ventilated areas of mines. Generally, changes in the barometric pressure have little impact on the atmosphere in the sealed area in a mine, except for the areas just inby and outby the seals. During a period of falling barometric pressure, the atmosphere tends to leak from the sealed area into the active workings of a mine. When the barometric pressure is rising, the atmosphere tends to leak from the active area into the sealed area. The barometric pressure for Buckhannon, West Virginia, at 12:00 a.m. on January 2 was approximately 30.01 inches of mercury. The barometric pressure was falling from 1:00 a.m. to 4:00 a.m. At 4:00 a.m., the barometric pressure was 29.92 inches of mercury. From 4:00 a.m. to 6:30 a.m., the pressure varied between 29.90 and 29.94 inches of mercury. The pressure was about 29.93 inches of mercury at 6:30 a.m.

Figure 13 is a graph of the barometric pressure for Buckhannon, West Virginia from 12:00 a.m. on January 1 through 12:00 a.m. on January 4, 2006. These



changes in barometric pressure did not appear to significantly influence the conditions within the sealed area just prior to the explosion, since the point of origin for this explosion was more than 300 feet from the seals.

**Figure 13 - Barometric Pressure for Buckhannon, WV**

### Roof Control Plan

MSHA approved a Roof Control Plan for the mine on October 16, 2003. Six-month reviews were conducted as required. MSHA completed the last six-month review prior to the accident on June 29, 2005.

MSHA approved four foot and six foot fully grouted resin bolts and five foot fully grouted resin tension bolts as the primary roof supports. Ten and fourteen foot resin cable bolts, prop setters, square and round plates, metal straps, wire mesh, brow tenders and other approved devices were used as supplemental support throughout the mine. Figure 14 shows pictures of square and round plates.



**Figure 14 - Square and Round Plates**

The approved plan required a four foot by four and a half foot roof bolt installation pattern in the main and sub main entries of the mine. The plan required the operator to bolt wire mesh to the roof of the track and belt conveyor entries during the roof bolting cycle, to within two bolt rows of the face. The wire mesh was required to be at least 8 gauge, with openings no greater than four inches square, and measuring at least five feet by thirteen feet overall. The wire mesh is shown in Figure 15.



**Figure 15 - Wire Mesh**

The plan required at least one of the following in the primary intake escapeway and one return air course entry maintained evenly with the section tailpiece:

- A roof sealant applied to the mine roof;
- A 17 inch square or larger plate (roof cap) installed with each roof bolt;
- Wire mesh bolted to the mine roof as described above; or
- Two rows of posts or equivalent supports installed to create a six foot wide walkway on not more than five foot advancing centers.

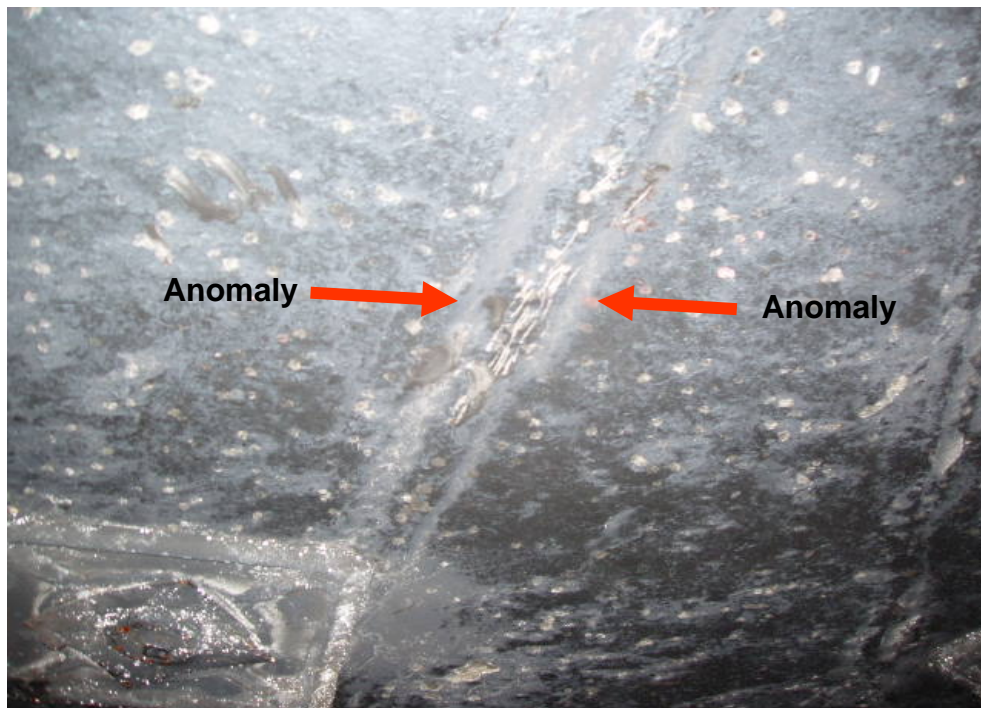
Of these four options, the mine operator installed the wire mesh in the primary intake escapeway and a return entry. The mine conveyor belt structure was suspended from the mine roof. Belt support brackets were anchored to the mine roof with roof bolts. These brackets and bolts were installed against the wire mesh for belt installation and not as roof support.

## Geology

The mine was developed in the Middle Kittanning Coal Seam. The overburden in the 2nd Left Parallel, measured from the base of the seam to the surface, ranged from 230 feet to 320 feet. The immediate roof consisted of gray shale grading upward into sandy shale and sandstone with shale bedding. A description of the mine geology and roof falls is contained in a report titled "Evaluation of Potential for a Roof Fall to Ignite a Methane-Air Mixture" in Appendix O.

### Evaluation of Two Linear Features near Survey Station 4010

Two linear geologic features were observed during the investigation. These two prominent features were located in the roof near survey station 4010, within the formerly sealed area of 2nd Left Mains. The features generated interest because they were located in the area where the explosion originated. Because the features seemed uncommon, they were referred to as "anomalies." Due to their location in the area where the explosion originated, some parties speculated that the linear "anomalies" might represent the effects of lightning. A picture of the anomaly is shown in Figure 16.



**Figure 16 - Anomaly**

Light brown linear streaks along the trend of the parallel linear ridges represent knife scratch marks from an attempt to collect fossil material. Location is the vicinity just in by survey station 4010 intersection. Twin parallel ridges pass beneath the embossed, square skin control plate.

An analysis of the features concluded that the linear features represent the remnants of a pair of fossilized trees, with each linear feature representing the top, tangential edge of a single tree. The rough texture of the linear feature represents the trace fossil impression of the tree bark as preserved against the bottom layer of the overlying muscovite-rich gray shale, and the pair of parallel ridges represents compaction of the muscovite-rich gray shale downward around the formerly circular boundary of the tree trunk. Although the fossil tree was removed by mining, the linear features represent the expression of the top edge of the tree where it tangentially contacted the bottom of the bedding plane exposed in the shale roof. An analysis and description of the linears near survey station 4010 is contained in Appendix P in two reports titled "Evaluation of Features" and "Description of Features Observed in the Roof Inby Spad 4010."

### **Cleanup Program and Rock Dusting**

The mine operator established a program for regular cleanup and removal of accumulations of coal and float coal dusts, loose coal, and other combustible materials at the mine. The program included an examination of active haulage ways prior to the end of each shift. Any loose coal accumulations were to be removed from the mine. Miners were to examine mining equipment used at the face and to remove accumulations of loose coal, coal dust, oil and grease before the end of each shift. They were also to remove any accumulations of loose coal, coal dust, oil and grease from the section tailpiece by the end of each shift. Rock dust was to be applied and maintained to within 40 feet of each working face. Accumulations of loose coal, coal dust or other combustibles along belt and track travel ways were to be removed or reported to the mine foreman each shift.

Rock dust was applied in the 2 North Mains and in 2 Left Mains during initial development. Additional rock dust was not applied in areas after they had been bottom mined. Miners stated that 36 one-ton bags and several pallets of 50-pound bags of rock dust were delivered to the track switch at the mouth of 2nd Left Parallel before the 2 North Mains seals were completed. Miners applied rock dust by hand and with rock dusting machines around the sealed area and outby the seals for a distance of approximately four crosscuts. According to miners, the depth of the rock dust in the area varied between one-half and three-fourths of an inch.

### **Mine Dust Survey**

Investigators conducted a post-explosion mine dust survey. The mine dust samples were analyzed at MSHA's Laboratory in Mount Hope, West Virginia. Each sample was subjected to an Alcohol Coke Test and an incombustible

analysis. The incombustible analysis identified the percentage of incombustible material in each sample. The Alcohol Coke Test identified the portion of coke in each sample. The results of the mine dust survey are contained in Appendix Q. The locations of all intended mine dust samples are shown on the mine map in Appendix R. Samples were collected by band or perimeter method from entries. Material was gathered from an area on the floor up to one inch deep and six inches wide and combined with dust from the roof and ribs to make up a one band or perimeter sample. The material was collected with a small flat scoop and brush, placed in a collection pan, and sifted through a 10 mesh screen. The sifted material was placed on a clean rubber sheet. If the amount collected was too large for the collection bag, then the sample was thoroughly mixed and quartered, reducing the desired amount to a half bag. If an insufficient amount was gathered, an additional, adjacent band sample would be taken. Where it was impractical or unsafe to collect full perimeter samples because of excessive height, a floor sample and a sample from the ribs was collected to the maximum height that could be done safely.

Each bag was long enough to allow tying a knot in the open end of the bag. An identifying tag was secured to each bag by the tag string and secured within the formed knot of the bag. As a sample was collected, the location was marked on the identifying tag that corresponded to the predetermined location on the mine dust survey map.

The incombustible content of the combined coal dust, rock dust and other dust must be maintained to at least 65% in the intake air courses and at least 80% in the return air courses, in the absence of methane, to meet regulatory requirements.

The area evaluated was extensive; therefore, the survey was divided into five separate survey areas, as follows:

Survey No. 1(a) - 2 North Mains (outby the location of the 2 North Mains seals)

Survey No. 1(b) - 2 North Mains (inby the location of the 2 North Mains seals)

Survey No. 2 - 1st Left

Survey No. 3 - 2nd Left Parallel

Survey No. 4 - 2nd Left Mains (inby the location of the 2 North Mains seals)

MSHA intended to collect mine dust samples at 685 designated locations.

However, 458 locations could not be sampled because of wetness, inaccessibility, or because the area was unsafe to travel. A total of 227 locations were successfully sampled.



## **2 North Mains - Survey No. 1(a)**

The starting point for this survey was 50 feet in by survey station 3483 of the 2 North Mains track entry, and extended in by for approximately 5,700 feet to the location of the 2 North Mains seals. There were 247 designated locations identified for sampling in this survey. A total of 141 mine dust samples were collected. The other 106 locations could not be sampled because of wetness, inaccessibility, or because the area was unsafe to travel. The results of the 141 samples collected indicate that 39 of the samples, or 28%, were substandard. However, due to the area where the explosive force propagated, it cannot be determined if these samples were contaminated by dust and other materials. Therefore, the incombustible content of the samples taken could not be used to determine compliance with the regulatory requirements.

## **2 North Mains - Survey No. 1(b)**

The starting point for this survey was in by the 2 North Mains seals and extending toward the faces of 2 North Mains. There were 64 locations identified for sampling. Mine dust samples were collected at 29 locations. The other 35 locations could not be sampled because of wetness, inaccessibility, or because the area was unsafe to travel. The results of the 29 samples collected indicate that 26 of the samples, or 90%, were substandard. The explosion occurred in by the seals and the incombustible content of the samples taken could not be used to determine compliance with the regulatory requirements.

## **1st Left - Survey No. 2**

The starting point for this survey was at the mouth of 1st Left. There were 43 locations identified for sampling in 1st Left. Mine dust samples were collected at four locations. The other 39 locations could not be sampled because of wetness, inaccessibility, or because the area was unsafe to travel. The incombustible content results of the four samples indicated that two of the four samples, or 50%, were substandard.

## **2nd Left Parallel - Survey No. 3**

The starting point for this survey was at the mouth of 2nd Left Parallel. There were 222 designated locations for sampling in 2nd Left Parallel. Mine dust samples were collected at 42 mine locations, the other 180 locations could not be sampled because of wetness, inaccessibility, or because the area was unsafe to travel. Of the 42 samples analyzed, 14 of the samples, or 33%, were substandard.

## **2nd Left Mains - Survey No. 4**

The starting point for this survey was at the mouth of 2nd Left Mains. There were 109 locations identified for sampling in the 2nd Left Mains. Mine dust samples were collected at 11 locations, the other 98 locations could not be sampled because of wetness, inaccessibility, or because the area was unsafe to travel. However, due to the area where the explosive force propagated, it cannot be determined if these samples were contaminated by dust and other materials. The results of the 11 samples collected indicate that 4 of the samples, or 36%, were substandard. Therefore, the incombustible content of the samples taken could not be used to determine compliance with the regulatory requirements.

## **MSHA Mine Dust Sampling Prior to Accident**

MSHA conducted mine dust surveys during regular health and safety inspections prior to the accident. The areas that were evaluated for incombustible content as required by Section 75.403 included areas beginning approximately 600 feet outby the 2 North Mains seals and extending through the sealed area and into 2nd Left Mains. Based on the inspectors' observations and evaluation, this entire area could not be sampled because of excessive water. Additionally, mining had stopped because of increased water inflow and deteriorating roof conditions. As discussed previously, a large area was evaluated before the accident and was very wet. Similar conditions were found after the accident. Therefore, it appears that the area may have also been wet at the time of the explosion.

## **Examinations**

Sections 75.360 and 75.362 require that examinations of the mine be conducted by certified mine examiners. Section foremen were normally assigned to conduct preshift and onshift examinations during production shifts. Hourly mine examiners were normally assigned to conduct preshift examinations on non-producing shifts. Other mine examiners were normally assigned to conduct onshift and preshift examinations along the belt and track entries.

Section 75.360 requires an examination by a certified person within 3 hours preceding the beginning of any 8-hour interval during which any person is scheduled to work or travel underground. The certified examiner is required to examine for hazardous conditions, test for methane and oxygen deficiency, and determine if air is moving in the proper direction at specific locations, such as travelways, working sections, and seals along intake air courses where intake air passes by a seal to ventilate working sections. The 2 North Mains seals were not required to be examined during preshift examinations unless miners were

scheduled to work in the area. Preshift examinations were performed based upon three 8-hour time periods. The 8-hour intervals scheduled for starting preshift examinations were 6:00 a.m., 2:00 p.m. and 10:00 p.m.

On Sunday, January 1, 2006, the day shift mine foreman and two other miners worked on the track and on a pump on the 2nd Left Parallel section. One of the hourly employees was a motorman who was also certified to conduct mine examinations. Preshift or supplemental examinations were not conducted prior to these employees entering the working area.

On January 2, 2006, two mine examiners, Helms and Jamison, conducted a preshift examination of the underground areas of the mine before the crews entered the mine. This break in routine was due to the holiday weekend. Jamison examined the 2nd Left Parallel section and exited the mine to complete his report. Helms examined the 1st Left section, remained underground and called his report to the surface. No unsafe conditions or dangers were noted or reported.

Section 75.364 requires a weekly examination of worked-out areas and the bleeder system. It also requires an examination for hazardous conditions at specific locations that include at least one entry of the intake and return air courses in their entirety and at each seal along a return or bleeder entry. Measurement of air volume and tests for methane at specific locations are also required. Hourly employees who were also examiners were assigned to conduct the majority of the weekly examinations. Interviews with mine personnel and a review of the weekly examination records conducted during the last quarter of 2005 indicated deficiencies. The records indicated that a weekly examination of the mine was not conducted during the week of December 14, 2005. The examiner conducting the weekly examination on November 23, 2005, failed to make the required air reading where air leaves the main return at the mouth of 1st Left.

The mine examiner conducting the weekly examination for hazardous conditions found and recorded 0.2% methane in the air course at the 2 North Mains seals on December 28, 2005. He also stated that he found 1.2% methane exiting the sample pipe at the No. 10 seal. This was the only time he had found methane during his examinations. The mine examiner reported the incident to the mine foreman. On December 30, 2005, the mine foreman found 0.2% methane in the split of air ventilating the seals.

Section 75.312 requires a daily main mine fan examination to assure electrical and mechanical reliability of each main mine fan and its associated components. This includes the devices for measuring or recording mine ventilation pressure. A trained person designated by the operator shall examine the fan for proper

operation at least once each day unless a fan monitoring system is used. Hourly and management employees are trained by the operator to conduct these examinations. Interviews with mine personnel and a review of the daily fan pressure recording charts indicated the operator failed to change the main mine fan pressure recording chart before the beginning of a second revolution on four occasions during the last quarter of 2005. The required test of the automatic fan signal device was not performed by stopping the fan every 31 days.

MSHA's underground and surface standards require the operator to examine and test electrical equipment at specific intervals. Section 75.512 requires all underground electrical equipment to be examined and tested at least weekly by a qualified person to assure safe operating conditions. Five pieces of equipment were not tested or examined consistently on a weekly basis. Section 75.900-3 requires all low- and medium-voltage circuit breakers and their auxiliary devices to be tested and examined by a qualified person on a monthly basis. The circuit breaker that protected the 58 horsepower (hp) pump was not tested or examined at least once each month. Section 75.900-4 further states that each breaker test, examination, repair, or adjustment will be noted in a written record. The record of the tests of all circuit breakers did not list each breaker individually. Section 75.800-3 requires the testing and examination of high-voltage circuit breakers and their auxiliary devices protecting underground circuits by a qualified person on a monthly basis. Section 77.502 requires all surface electrical equipment to be examined, tested and properly maintained by a qualified person at least monthly, to assure that it is in safe operating condition.

### **Training**

The approved Part 48 Training Plan for underground and surface areas of the mine was evaluated to assure that the plan met the requirements of Section 48.3 and Section 48.23. Course material, course outlines, evaluation methods, visual aids, and equipment available for use by the instructor(s) as required by Section 48.3(e) and Section 48.23(e) were reviewed. A review of all Task Outlines was conducted for each position at the mine, as required by Section 48.3(b) (8) and Section 48.23(b) (8). Evaluations were done of the mine operator's MSHA Form 5000-23, Certificates of Training, with emphasis on the 1st Left and 2nd Left Parallel crews. The course material, course outlines, evaluation methods, visual aids, and equipment used for training were reviewed to assure that all items listed in the Approved Part 48 Training Plan were available for use by the instructor(s) as required by Section 48.3(e) and Section 48.23(e). The approved Part 75 and Part 77 training plans for certified and qualified persons were reviewed. Course materials and course outlines for Part 75 and Part 77 including but not limited to, Principles of Mine Rescue, Provisions of Part 75 and Part 77, and task training as required by Section 75.161 and Section 77.107-1 were evaluated.

A list of miners that carry a methane/oxygen detector was requested from the mine operator. These miners were checked on the MSHA Standardized Information Systems (MSIS) to ensure that they had been tested as required by Section 75.151 and Section 77.102. The electrical retraining plan for underground and surface as required by Section 75.153(g) and Section 77.103(g) was reviewed. A list of electricians at the mine was checked on MSIS for up-to-date certifications. All instructors that conducted training for the mine, which included Part 48 Approved Instructors and Electrical Instructors, were checked for up-to-date qualification on the MSHA MSIS program. The Mine Emergency Evacuation and Firefighting Program of Instruction was reviewed and compared to the course outlines in Sections 48.25, 48.6, and 48.8, to assure that the outline addressed the needs of the miners.

The following is a list of deficiencies that were found:

- Ten miners whose job duties required testing for methane had not demonstrated to the satisfaction of an authorized representative of MSHA that they were qualified to test for methane;
- The annual refresher training was not adequate. A miner was not provided with hands-on SCSR training;
- Underground electrical qualification retraining was conducted at the mine without an approved underground electrical retraining program;
- Surface electrical qualification retraining was conducted at the mine without an approved surface electrical retraining program;
- A form 5000-23 was signed by a miner and a qualified instructor verifying that annual refresher training had been completed when in fact no training had been given; and
- Six miners did not receive any annual retraining as required.

## **Communications**

### **Equipment**

The mine used several communication systems. The dispatcher's office was the communications hub. Verizon supplied telephone service to the surface office buildings and the dispatcher's office. The dispatcher had the capability to route the Verizon service into the mine through the mine phone system.

The underground mine phone system was comprised of pager phones, which were located throughout the mine and in the working sections, as well as in the pit area, dispatcher's office and other mine offices. Any pager phone on this system could page to all of the other pager phones. A conversation between any two people using these phones could be heard from any of the other pager

phones. This system allowed a number of miners to communicate with each other simultaneously.

Mine pager phones were connected together by two wires. Each phone had a battery. If the battery was disconnected or depleted, then that phone would not operate. If the wiring became severed, then there would no longer be two-way communications between the phones inby the damage and the phones outby the damage. However, the phones outby could communicate with each other and the phones inby could communicate with each other.

The mine also employed a Gai-Tronics Corporation trolleyphone communication system. These phones were located in the dispatcher's office and on the battery powered rail mantrips and locomotives. Although the system was referred to as a trolleyphone system, there was not an electrically-powered trolley system at the mine. The trolleyphone system used an antenna wire, a carrier repeater and an electrical connection to the track at the drift opening and at the carrier repeater. The antenna wire was installed on the mine roof above the track. The carrier repeater was used to amplify the signal to maintain trolleyphone communication throughout the mine. It was installed in the crosscut between the No. 4 Belt entry and the No. 5 track entry, 9 Crosscut, No. 4 Belt. The carrier repeater was powered by 120 volts received from the No. 4 Belt power center installed at the same location.

The trolleyphone system allowed communication between miners on mantrips and locomotives, and the dispatcher. This system could receive communications from the pager phone system, but could not transmit to it. When needed, the dispatcher would relay communications between the two phone systems.

The trolleyphone system would not operate if the carrier repeater was de-energized. For example, if the power center for the No. 4 Belt drive was de-energized, the repeater would be de-energized and the trolleyphone system would not operate. If the antenna wire to the system was damaged, trolleyphones inby the damage would not function, but those outby the damage might.

Motorola two-way handheld radios were used on both sections. The two-way radios would not interact with any other communication system. MSHA personnel indicated the radios may have a maximum range of 1,500 feet within the same entry, with severely limited range around corners. This range is highly dependent on coal seam height, entry geometry, and infrastructure within the entry. Battery strength also affects the range of the radios. One miner stated that the units had a range of about 1,000 feet when in direct line of sight and less than that distance when not in direct line of sight.

The dispatcher and the yardman each had a handheld radio. These radios could transmit and receive communications with each other and the pager phones via the Interlink 3000 unit located within the dispatcher's office. The radios could also receive alerts and alarms from the AMS. The dispatcher used the radio when his assignments required him to leave the dispatcher's office.

### **Equipment Status**

The pager phone system was operational prior to the accident. The explosion damaged wiring and several pager phones. The most outby damage to the wiring occurred approximately 50 feet inby the 1st Left track switch, near survey station 3869. Pager phone communication inby this point to 2 North Mains and 2nd Left Parallel was no longer possible. Information on the mine pager phone is included in Appendix S, which is an executive summary of a report entitled "Executive Summary of Inspection of Sago Mine Voice Communications Equipment."

At the start of the day shift on January 1, 2006, the trolleyphone system did not function. The carrier repeater for the system lost power. At about 8:00 a.m., a maintenance foreman reset the circuit breaker and the trolleyphone system worked. The trolleyphone system was working at the end of this shift.

The dispatcher indicated that the trolleyphone system again failed to function on January 2, 2006. Before the accident, he only heard static on the system. After the explosion, the carrier repeater lost power. The most outby damage of the antenna wire was approximately 20 feet inby survey station 3854, located near 50 Crosscut, No. 4 Belt. The trolleyphone system could not be used to communicate with the mantrip used by the 2nd Left Parallel crew. During the investigation, the carrier repeater was removed from the mine and tested, and was found to be functional. The executive summary of the reports for the trolleyphone system are contained in Appendices S and T.

The 1st Left crew was located at the track switch when the explosion occurred. It is over 1,400 feet from the 1st Left track switch to the location of the 2nd Left Parallel mantrip. These two locations were not in a direct line of sight. Therefore, it is not likely that the 1st Left and 2nd Left Parallel crews could have communicated with each other with the radios. An "Executive Summary of Investigation of the Motorola Two-way Radios" is contained in Appendix U.

## **Mine Rescue Communications**

The following surface locations at the mine had pager phones during the mine rescue operations:

- Command center (mine superintendent's office)
- Maintenance superintendent's office
- Small office behind the maintenance superintendent's office
- Mine foreman's office
- Foremen's office
- Dispatcher's office
- MSHA's mine rescue vehicle (phone was connected between 6:00 p.m. and 12:00 midnight on January 2, 2006)
- WVMHS&T's mine emergency vehicle (phone connected during rescue efforts)
- Building in mine pit (phone disconnected at approximately 6:58 a.m. on January 3)

A command center was established at about 1:00 p.m. on January 2, 2006 in the mine superintendent's office.

### **Underground Mine Rescue Communications**

Mine rescue teams used Motorola two-way handheld, MSHA approved permissible radios. During this rescue operation, MSHA provided four units, but one malfunctioned. Interviews conducted with each MEU team member and their surface support personnel determined that the handheld permissible radio communication system performed as expected. Communications are difficult in mine rescue scenarios where rescuers are wearing full face masks.

Literature provided by the radio manufacturer discusses the range of the radios in general terms. The literature states that more power will increase the range. As the batteries discharge power, the range of the radios will decrease. In addition, proper tuning will increase the range of the radios. The range is shorter in a building than it is when used outside in an area with no obstructions. The range for the permissible radios is similar to that of the non-permissible radios discussed previously when used underground.



## Seismic Location System

### Introduction

In 1970, the National Academy of Engineering (Academy) reported that a seismic system might be able to detect and locate trapped miners. The Academy proposed that a miner could strike part of the mine with a heavy object and the resulting vibrations could then be detected on the surface by using seismic transducers or geophones. The vibrations would be converted into electrical signals by the geophones and then amplified, filtered, and recorded. By comparing the arrival times of the signal at several different geophone locations, the trapped miner could be located.

In 1971, the Westinghouse Electric Company built and tested a truck-mounted system. From 1972 until 1981, Westinghouse, MSHA and the USBM modified and tested the system in a variety of mines. There were 15 field tests conducted to define a signal model, background, noise levels, and geophone location performance. Since 1981, MSHA has conducted intermittent field tests to check and maintain operational familiarity with the system.

Tests indicated that, under certain conditions, the truck-mounted system can be an effective means of detecting and locating trapped miners. Signals from miners pounding on the roof of a mine can be of sufficient strength to enable detection over an area of the mine. The signals are affected by ground conditions, the depth of the mine, and seismic noise sources. Estimations of the location of the trapped miner can be of sufficient accuracy to aid the rescue team or aid in the positioning of the rescue drill.<sup>34</sup> However, a significant amount of time is required to set up the system and conduct an accurate survey.

MSHA's truck-mounted seismic location system is maintained by personnel from the Pittsburgh Safety and Health Technology Center of MSHA's Technical Support. The seismic equipment, as well as the other related mine emergency equipment and personnel, is not automatically deployed when a mine emergency, such as a fire or explosion, occurs. The deployment of the equipment is based on the preliminary information received about the nature of the mine emergency, and is often made based on consultation with Technical Support personnel.

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<sup>34</sup> Evaluation of the Seismic System for Locating Trapped Miners, Bureau of Mines Report of Investigations, RI 8567, John Durkin and Roy J. Greenfield, (1981).

A minimum of six people are required to prepare and operate the system in a timely fashion. The Chief, Mine Emergency Operations (MEO), directs the setup and operation of the system, assisted by two Technical Support personnel. Several MSHA MEU team members have also been trained to assist in the setup and operation of the system. However, the use of the MEU at a mine emergency for this purpose could reduce the resources available for mine rescue exploration.

In March 1977, during the rescue efforts at the Porter Tunnel Mine Inundation near Tower City, Pennsylvania, the MSHA truck-mounted seismic system was deployed and was not able to detect signals from a trapped miner, due to seismic noise and overburden conditions, using geophones installed on the surface over the mine. MSHA installed cables and geophones from the surface into the mine, attempting to receive signals from miners. This also was not successful. This event prompted MSHA to develop a mini-seismic system in the 1980's. This system was designed to be quickly deployed. It is portable and designed to be taken underground and used by mine rescue teams. The system can be carried by two people and will easily fit in a small truck. However, the mini system has very limited capabilities, employing only 4 geophones. It cannot pinpoint the specific location of miners, but may detect their presence in some situations. It was not designed to be used from the surface of a mine. However, when used in this configuration, it can detect signals at a very limited depth, reportedly less than 200 feet.

### **System Deployment**

Following a mine disaster in which it has been determined that use of the seismic location system would be helpful and is requested to be deployed, the system is transported to the mine site. A geophone array is positioned over the suspected area of entrapment. Each of the seven geophone sub-arrays must be accurately surveyed and tied to the mine survey. A refraction survey must also be performed to determine the ground velocities. In order to improve the possibilities of detecting and locating a trapped miner, the geophones should be placed around the miner's most likely location. If the trapped miner is not within the area covered by the geophones, he may still be detected, but determining his location accurately may be more difficult. The system does not give an exact location for the trapped miners. Information from the system, along with the underground mine maps, helps determine where miners may be located. The accuracy of the system is limited to 50-100 feet.

Telemetry is used to connect the system base station with the geophone arrays. It is important to locate the geophones away from any vehicle or personnel activity during attempted reception of seismic signals, because they interfere

with signal reception. Other natural and man-made seismic noise sources hinder the system's ability to detect signals from trapped miners

### **Mine Emergency Evacuation and Firefighting Program of Instruction**

The Program provided that when miners are trapped by toxic gases from fires or explosions and are able to take refuge where the air is comparatively good, they should make every effort to protect themselves from deadly, poisonous gases by erecting a barricade or bulkhead. The miners behind the barricade should do the following:

- 1) Listen for three shots, then
- 2) Signal by pounding hard on the roof 10 times.
- 3) Rest for 15 minutes, and
- 4) Repeat . . . until 5 shots are heard which would indicate that you have been located.

### **2nd Left Parallel Crew**

After attempting to evacuate, the 2nd Left Parallel crew built a barricade in the face area of 2nd Left Parallel. The miners used a sledgehammer to pound on a roof bolt. Investigators found the sledgehammer and an obviously beaten roof bolt in the barricade. McCloy indicated that they took turns pounding but he was unable to provide a time as to when they started or stopped. It is likely that they started pounding in the morning of January 2, and stopped in the afternoon or evening of that same day. The exact timeframes are unknown.

### **System Response**

MSHA headquarters personnel contacted the Chief, MEO, Dr. Jeffery Kravitz at about 10:15 a.m. Only limited information was available at the time, including the fact that an explosion may have occurred at the mine, that a number of miners underground had not been accounted for, and that miners had gone underground after the event. Based on this information, headquarters personnel requested Kravitz to dispatch MSHA's mine rescue and gas analysis equipment and personnel to the mine.

Kravitz's first priority was to notify MSHA district managers to request that their mine rescue team members respond to the mine. He then started contacting the required MEU members at their homes. At about 12:30 p.m., Kravitz instructed his staff members to prepare the truck-mounted seismic system for possible deployment to the mine. He called the trucking company that hauls the supply trailer, which is an integral part of the system, and put them on alert. At 2:00 p.m., Kravitz traveled to Pittsburgh and then went to the Technical Support

offices. The mini-seismic system was readied for deployment in the event it was needed. He departed with it at 5:15 p.m., arriving at the mine at 8:30 p.m.

MSHA officials at the mine had gathered information about the accident throughout the day on January 2 and updated headquarters staff on the situation. They learned that the 1st Left crew and the other miners who were outby 1st Left at the time of the explosion evacuated the mine safely. They concluded that an explosion had occurred and that the 2nd Left Parallel crew did not evacuate. Miners entered the mine, found damaged ventilation controls that had short circuited the ventilation system, and made temporary repairs to those controls to advance the ventilation in the mine to the mouth of the 2nd Left Parallel. At this location, they encountered smoke, elevated CO concentrations and insufficient ventilation current to continue, and evacuated the mine. The early information indicated that the explosion occurred somewhere on 2nd Left Parallel and that the miners were still located there. Mine rescue teams arrived at the mine throughout the day. The mine operator had started work on surveying the area on the surface over 2nd Left Parallel to drill a borehole, but the survey effort was hampered by conditions and the lack of appropriate survey equipment on site. Although there was an initial upward trend in the gas concentrations at the monitoring locations, the trend eventually went downward, making it likely that mine rescue teams could enter the mine.

Based on this information, MSHA officials decided that the approximate location of the miners was known and that mine rescue teams would be able to enter the mine if the downward trend continued. The truck mounted seismic system would take over eight hours to set up once a surveyed location was determined, and all rescue operations, including drilling, would have to cease during the test. Therefore, the truck-mounted seismic system was not deployed to the mine site.

The terrain and depth of cover over the 2nd Left Parallel made use of the mini-seismic system from the surface impractical, so it was not used. Preparations for a borehole into 2nd Left Parallel were ongoing. The mine rescue teams were progressing steadily underground and did not need it.

## **Seals**

### **Manufacturing and Testing of Omega Block**

Seals are constructed in underground coal mines to separate the worked-out areas from the active workings. Stoppings and other ventilation controls are also constructed to direct ventilation through the mine. Seals, stoppings, and other controls can be constructed from a variety of materials, provided that these materials and the methods of construction have been deemed suitable by MSHA. In order for MSHA to determine that seal materials and the methods of

construction were suitable, full scale seals were constructed and tested underground in NIOSH's Lake Lynn Experimental Mine (Lake Lynn). Lake Lynn is an underground limestone mine that was converted into a federal research facility. Prior to the accident, seals had been built from various materials and tested at Lake Lynn by utilizing different methods of construction and subjecting the seals to explosions generating a static pressure of 20 psi or more. This 20 psi testing pressure was required by federal regulation and was based on USBM research. MSHA accepts materials for use as seals provided they are constructed in the same manner as tested. Materials such as solid concrete blocks, wood, pumpable cementitious materials, and lightweight blocks, such as Omega blocks, had passed this explosion testing prior to December 31, 2005 and been accepted for use as seals.

If an explosion occurs in direct line with any seal, the total pressure from the explosion is exerted on the seal. The total pressure is the sum of the static pressure and dynamic pressure. The static pressure is pressure exerted in all directions. The dynamic pressure is the pressure exerted by the movement of gases, or wind pressure. For example, an explosion in an entry exerts a static pressure only on seals destroyed in crosscuts and exerts the total pressure on seals destroyed in the same entry. During explosions, seals are exposed to either, 1) the static pressure only if the seal is not in the direct line of the explosion, or 2) the total pressure, including both static and dynamic pressure, if the seal is in the direct line of the explosion and is destroyed.

Omega blocks are lightweight, polyester fiber-reinforced blocks manufactured by Burrell Mining Products International, Inc. (Burrell). The nominal size of a single block is 8 inches by 16 inches by 24 inches, weighing between 40 to 50 pounds. Laboratory testing has shown that Omega blocks are noncombustible. Figure 17 shows a picture of an Omega block.



**Figure 17 - Picture of an Omega Block**

MSHA initially approved Omega blocks as a construction material for stoppings. However, full-scale testing at Lake Lynn revealed that Omega blocks could be used to build seals that withstand a static horizontal pressure of 20 psi. Since 1990, various configurations of Omega block seals had successfully passed testing. The initial Omega seal which passed explosion testing was 24 inches thick and included a center pilaster and hitching. In 2001, a 40 inch thick Omega seal without a pilaster or hitching passed explosion testing. The proper construction of Omega seals will be detailed in a subsequent section of this report.

Burrell manufactures Omega blocks at plants located in Bluefield, West Virginia; Garards Fort, Pennsylvania; and Price, Utah. Burrell produces other products at these plants as well. At each plant, the manufacturing occurs in a facility adjacent to an enclosed storage area. After manufacturing, the Omega blocks are protected from the environment in an enclosed storage area.

Suppliers provide the necessary ingredients to each plant for the manufacture of Omega blocks. The ingredients include Portland cement, water, foaming agent, polyester fiber, and Type F fly ash. The cement and fly ash are very fine powders. A computer-controlled system combines the ingredients into a batch mix. After appropriate quantities are entered, a mixing process occurs, which results in a uniform distribution of ingredients throughout the mix. The batch is discharged from the mixer, and a Burrell employee pumps it into forms. The employee must maintain the discharge hose in continual motion to properly fill the forms. As individual forms are filled, they are moved from the filling area to a holding area for approximately 24 hours. This period allows the product to harden to the point where the forms can be removed. A full curing period is 28 days due to the cement in the mix.

After 24 hours, pallets of filled forms are individually positioned at a large, electronically-controlled band saw. According to Burrell, allowing the material to cure longer than 24 hours prior to sawing would cause excessive wear on the saw. When the forms are removed, the material is cut into 8 inch by 16 inch by 24-inch sections. As individual pallets of Omega blocks complete the sawing phase, they are subjected to a quality control check. Initially, visual observations are made of each pallet load of cut Omega blocks. Any Omega blocks with defects or obvious differences in dimensions are removed from the pallet and discarded. A single block from each pallet is examined for size and weight. During this phase, Omega blocks generally weigh between 45 and 47 pounds. Blocks must weigh between 40 pounds and 50 pounds to be acceptable. Up to five pounds of water loss may occur in individual blocks during the curing phase.

After the quality control check is completed, a shrink wrap is fitted to each pallet load of Omega blocks. This wrap protects the Omega block from atmospheric conditions, such as precipitation, and serves to maintain the integrity of the block during the curing and shipping process. An identification tag is affixed to each pallet with a date stamp marked on it to show the manufacture date. Each pallet is moved to a storage area where it is kept for at least two weeks before shipping. This two week period allows for continued curing of the Omega blocks. Omega blocks are shipped directly to underground coal mines or to mine supply distributors.

Uniaxial compressive strength tests were conducted on Omega blocks from a variety of sources. The purpose of the testing was to establish whether any strength differences existed between dry and wet block, between new block from each of the three plants, between blocks from lots used previously at Lake Lynn, or between blocks cored from different sides. Preparation and testing was conducted by MSHA's Roof Control Division at their Bruceton facility. The complete results of all uniaxial compressive strength tests of Omega blocks are contained in a Report of Laboratory Testing dated July 11, 2006. Appendix V is a copy of the executive summary of that report. The Omega blocks were received from ten (10) separate locations as follows:

1. Burrell's Bluefield, West Virginia plant
2. An underground coal mine in Utah
3. NIOSH's Lake Lynn - 2002
4. NIOSH's Lake Lynn - 2006
5. Sago Mine -2 North Mains seal remnants
6. Sago Mine - Supply yard blocks dated 2004
7. Sago Mine - Supply yard blocks dated 2005
8. Sago Mine - Supply yard loose blocks undated
9. Burrell's Price, Utah plant
10. Burrell's Garards Fort, Pennsylvania plant

Burrell does not conduct compressive strength testing on any Omega blocks manufactured at any of their three plants. Therefore, no direct comparisons could be made between the Omega blocks tested as a part of this investigation and results of past testing during the manufacturing phase. A range of compressive strengths between 45 psi and 120 psi is typical for Omega blocks. Of the 109 samples tested, 108 (99.1%) samples fell within or exceeded the expected range. Only one (0.9%) sample fell below expectations.

The results indicate that there are no differences in the average compressive strengths between wet and dry specimens or between cores removed horizontally or vertically with a drill. Core orientation had little influence on compressive strength since the Omega material is a mixed product poured into a

mold. Sample degradation (i.e. surface cracking) was observed as samples dried. However, moisture content did not influence the compressive strength.

## **Seal History and Construction**

Federal regulations require that areas of underground coal mines be ventilated or sealed. Sealing eliminates exposure to hazardous conditions, such as adverse roof conditions, and allows for areas to be abandoned where mining has ceased. Sealing eliminates the need to ventilate and examine sealed areas. Many underground coal mines choose to construct seals. Seals are to be constructed according to the federal regulations contained in Section 75.335. In addition, Section 75.335 (a) (2) permits seals to be constructed using alternative methods or materials if they can withstand a static horizontal pressure of 20 psi.<sup>35</sup> The method of installation and the material used are approved in the ventilation plan.

Prior to 1992, federal regulations stated that pending the development of specifications for explosion-proof seals or bulkheads, seals or bulkheads could be constructed of solid, substantial, and incombustible materials sufficient to prevent an explosion that may occur on one side of the seal from propagating to the other side. There were no performance standards prior to 1992 that defined seal construction. However, in 1992, MSHA promulgated revised safety standards for underground coal mine ventilation. The standards included a 20 psi static horizontal pressure requirement on seals constructed of alternative methods or materials. The 20 psi requirement was based on USBM Report of Investigations (RI) 7581 entitled "Explosion-Proof Bulkheads." According to RI 7581, a seal or bulkhead may be considered explosion proof when its construction is adequate to withstand a static load of 20 psi, if there is sufficient incombustible material on both sides of the seal to abate the explosion hazard. With adequate incombustible material and minimum coal dust accumulations, USBM considered it doubtful that pressures exceeding 20 psi could occur very far from the origin of the explosion. The coal mining industry and the general public were afforded the opportunity to comment on the proposed ventilation regulations before those regulations became effective. The regulations were intended to prevent explosions on either side of a seal from propagating to the other side.

MSHA partnered with NIOSH to develop a full-scale seal-testing program at Lake Lynn. Figure 18 is a sketch of Lake Lynn. Alternative seal designs have

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<sup>35</sup> MSHA has since issued an interim requirement that newly constructed seals must withstand a 50 psi overpressure. MSHA PIB No. P06-16.



been tested and determined to meet the requirements of 75.335(a)(2). Seals that MSHA has determined to be suitable for construction in underground coal mines included seals constructed of Omega blocks. All seals that are deemed suitable for construction in underground coal mines must be constructed in the same manner as those that passed explosion testing at Lake Lynn. The size limitations for all seals are not to exceed 8 feet in height or 20 feet in width. Seals can be constructed in larger openings but they must be evaluated by MSHA on a case-by-case basis prior to installation. Deviations in the method of construction or the materials used result in an untested seal with strength characteristics that may not be appropriate. Consequently, such seals are not suitable for construction in underground coal mines until they successfully pass testing.

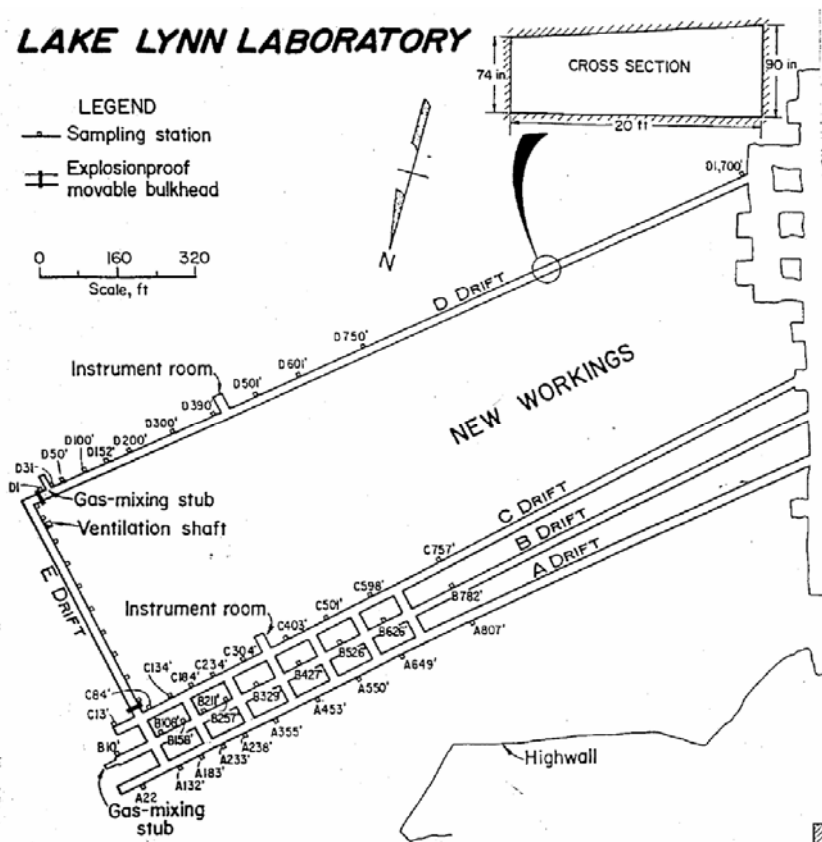


Figure 18 - Sketch of the Lake Lynn Mine

When the full-scale testing program was initiated, manufacturers submitted their intended designs to MSHA and the USBM. Seal designs were evaluated to determine whether their intended purpose could be met. Seals were constructed underground at Lake Lynn and provided time to cure. The USBM documented the steps necessary for construction. Air leakage guidelines were developed regarding the amount of air leakage that would be acceptable at various air pressure differentials. Visual observations and air leakage tests were used to determine if the seal met the regulatory requirements. The guidelines show that an air leakage of up to 100 cfm is acceptable at an air pressure differential of one

inch water gauge and up to 250 cfm is acceptable at an air pressure differential of four inches of water gauge. A pre-explosion air leakage test was conducted. Seals were required to meet or exceed the guidelines. Afterwards, an explosion was initiated which generated a pressure of about 20 psi static horizontal pressure on each seal. Subsequent to testing, seals were again required to meet the air leakage guidelines.

Manufacturers shared their successfully tested designs with mine operators. Mine operators submitted some of these designs for inclusion in their ventilation plan to MSHA for approval. The MSHA district office could contact MSHA Technical Support for technical information and guidance on any specific seal design prior to approval. MSHA Technical Support provided training, distributed technical information, and responded to specific inquiries regarding seal construction.

The manufacture and testing of individual Omega blocks has been described in a previous section of this report. Omega blocks had been found suitable for seal construction, when mortared together with BlocBond in the proper configuration. The first Omega block seals which passed explosion testing were 24 inches thick, including a 48 inch square center pilaster and hitched six inches deep along both ribs and the floor. A pilaster is an additional center column built of Omega blocks from floor to roof as an integral part of any individual seal. Hitching is accomplished by cutting a trench along the floor from rib to rib and cutting a trench in each rib from roof to floor. The seal is to be set into the hitch as a means to prevent perimeter failures. Attaching angle iron to both ribs and the floor on both sides of the seals is an acceptable method for providing artificial hitching. The 24 inch thick Omega block seals successfully passed explosion testing and were deemed suitable for construction in underground coal mines.

In 2001, the 40 inch thick Omega block seal design without a pilaster or hitching passed explosion testing at 20 psi. As with other seals, there was no attempt to test these seals to their maximum strength. Consequently, the maximum explosive force which a 40 inch thick Omega block seal could withstand was not determined at that time. The construction of the 40 inch thick Omega seal is documented in a NIOSH publication titled, "Designs for Rapid In-Situ Seals" and includes adequate site preparation, roof support, and the following necessary factors:

1. No hitching was used.
2. Joints were staggered.
3. Final seal thickness was 40 inches plus the thickness of face coatings.

4. BlocBond, a high-strength mortar, was applied ¼-inch thick as a mortar for all vertical and horizontal joints and as a face coating on both sides of the seal.
5. No pilaster was used.
6. The gap between the top of the seal and the roof was about 2.5 inches.
7. Three rows of 1 inch thick by 8 inch wide by 10 feet long wood planks were run lengthwise from rib to rib across the top of the seal. One row was placed in the middle of the seal and two rows were placed symmetrically on each side with their respective edges flush with the inby and outby side of the seal. Each row was wedged on about 1 foot centers and the gaps between wedges and between wood rows were filled with BlocBond.

At the Sago Mine, the mine operator planned to construct seals across the nine entries of the 2 North Mains, which would effectively seal the inby areas of the 2 North Mains and all of the 2nd Left Mains. As a result, the mine operator submitted a plan detailing the construction of 40 inch thick Omega block seals. The plan, which was approved by MSHA, provided details on the method of construction of the 40 inch thick Omega seal. The applicable addendums to the plan are included in Appendix K. The plan included the following:

1. No hitching was to be used.
2. Total thickness of the completed seal shall be 40 inches.
3. Joints were to be staggered.
4. All joints shall be a minimum ¼-inch thick and be mortared using BlocBond.
5. Three rows of wood planks running the entire length of the seal shall be installed across the top of the seal.
6. Wedges will be placed on one foot centers or less with BlocBond used to fill the gaps.
7. BlocBond shall be used as full face coating on both sides of the seal.
8. The opening where the seal is to be constructed was limited to 8 feet in height and 20 feet in width.
9. Seals shall be at least 10 feet from the corner of the pillar.

Subsequently, the mine operator submitted plans for the construction of Omega Block seals in locations where the opening is up to 10 feet high and 20 feet wide and also where the opening is up to 12 feet high and 20 feet wide. However, these plans were intended for future seal locations and not for the seals constructed in 2 North Mains. The method of construction for these larger designs was never utilized by the mine operator. The dimensions of the locations in 2 North Mains where the ten seals had been constructed were measured and are listed in Table 9.

**Table 9 - Dimensions of the 2 North Mains Seals**

Seal No.	Maximum Width (feet)	Maximum Height (feet)
1	21.7	8.9
2	20.4	8.7
3	19.7	7.4
4	18.9	7.3
5	18.8	7.2
6	19.5	7.4
7	19.2	7.5
8	19.6	6.3
9	19.1	6.7
10	18.3	6.3

Testimony indicated that:

- Mine management knew prior to seal construction that the location of the No. 1 seal exceeded 20 feet in width.
- Up to three inches of dry BlocBond was spread on the floor prior to seal construction.
- Each course was laid dry and mixed mortar was spread across the top of each course and an attempt was made to force mortar into the vertical joints by hand. This is shown in Figure 19. The darker material is the BlocBond, which only slightly filled the vertical joint.
- Three wood planks were not always used on top of seals and wedges were not always installed properly.



**Figure 19 - Mortar in Vertical Joint**

Similar seals were constructed at Lake Lynn and withstood a 21 psi explosion. The pressures created by the explosion at Sago Mine significantly exceeded 20 psi. The differences in seal construction, listed above, did not affect their ability to withstand the explosion.

Statements indicated that dry BlocBond was spread across the mine floor at each seal location as the initial step in seal construction. A dry powder such as BlocBond must be properly mixed with quantities of water designated by the manufacturer to form mortar. The quality of the BlocBond observed after the explosion varied. The BlocBond which remained on the ribs appeared to be properly mixed. It remained attached to the ribs after the explosion. It was dark gray to black and was extremely difficult to remove. The BlocBond observed on the floor, after Omega blocks were removed, was light gray and easily removed.

Core samples were removed from the floor at each of the ten seal locations. These samples were submitted to an independent laboratory to establish the quality and composition of the mortar in the setting beds. The laboratory studies included petrographic examinations, visual examinations, and compressive strength testing. A memo and executive summary of the report on the "Sampling and Testing of Mortar Bed Cores Taken from Failed Ventilation Seals" is included in Appendix W.

The average compressive strength of the mortar cast in the laboratory exceeded 8000 psi. Only one mine core sample had a comparable compressive strength, however, the remaining mine core samples only had strengths from 830 to 2810 psi. Strength discrepancies in the mine core samples occurred because of inadequate mixing, incorrect water contents, inclusion of extraneous materials, or from fissures or tears that occurred after the mortar stiffened.

The ten 2 North Main seal locations were evaluated during the investigation. The post-explosion location of Seal No. 1 is shown in Figure 20. Several whole and partial Omega blocks remained at the location of Seal No. 1 after the explosion. An exposed horizontal layer of BlocBond was easily removed from the remaining Omega blocks, indicating the lack of good bonding. No BlocBond was observed in some vertical joints. This seal had been constructed on a diagonal and was not perpendicular to either rib.



**Figure 20 - Post-Explosion Location of Seal No. 1**

The post-explosion location of Seal No. 2 is shown in Figure 21. Several Omega blocks remained at the location of Seal No. 2 after the explosion. Unburned paper material was observed imbedded within the mortar along one rib and also in a remaining joint between Omega blocks. No significant thickness of BlocBond was found between remaining Omega blocks. The vertical joint between two Omega blocks included BlocBond for only approximately 25% of the joint.



**Figure 21 - Post-Explosion Location of Seal No. 2**

The post-explosion location of Seal No. 3 is shown Figure 22. BlocBond on the rib was difficult to remove, indicating proper mixing prior to application. BlocBond on the floor had very little strength, indicating improper or no mixing with water prior to application.



**Figure 22 - Post-Explosion Location of Seal No. 3**

The post-explosion location of Seal No. 4 is shown in Figure 23. BlocBond was observed on the floor as a smooth surface, indicating a lack of adherence to the Omega block.



**Figure 23 - Post-Explosion Location of Seal No. 4**

The post-explosion location of Seal No. 5 is shown in Figure 24. BlocBond and Omega blocks were set on loose floor material at this location.



**Figure 24 - Post-Explosion Location of Seal No. 5**

The post-explosion location of Seal No. 6 is shown in Figure 25. It appeared that pieces of Omega block were used, along with dry BlocBond, to level the floor prior to construction of the seal.



**Figure 25 - Post-Explosion Location of Seal No. 6**

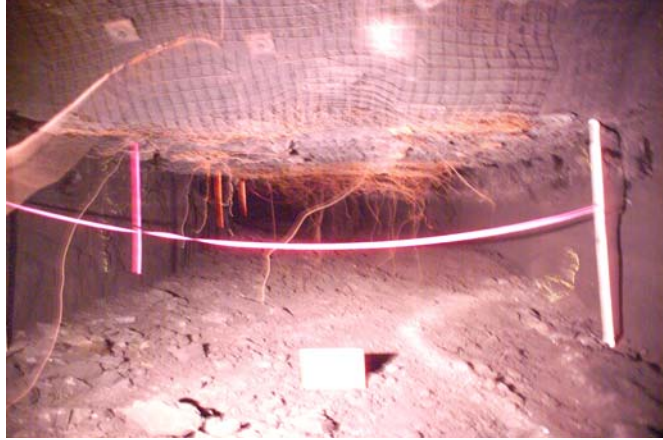
The post-explosion location of Seal No. 7 is shown in Figure 26. Very little BlocBond was observed on the ribs. The BlocBond was difficult to remove, indicating good strength characteristics.



**Figure 26 - Post Explosion Location of Seal No. 7**



The post-explosion location of Seal No. 8 is shown in Figure 27. Very little BlocBond was observed on the ribs. The BlocBond was difficult to remove, indicating good strength characteristics. Roof conditions deteriorated during the investigation at this location.



**Figure 27 - Post-Explosion Location of Seal No. 8**

The post-explosion location of Seal No. 9 is shown in Figure 28. Several Omega blocks remained at the location of Seal No. 9 after the explosion. Unburned plastic and paper material was observed imbedded within the mortar along one rib. A coating of dry, unmixed BlocBond was observed on the floor.



**Figure 28 - Post-Explosion Location of Seal No. 9**

The post-explosion location of Seal No. 10 is shown in Figure 29. No Omega blocks remained on the floor. There were some indications of mortar on the ribs.



**Figure 29 - Post-Explosion Location of Seal No. 10**

The actual construction of the ten seals was different from the requirements of the MSHA approved plan and from the initial NIOSH testing of 40 inch thick Omega block seals. Unburned plastic was imbedded inside the cured mortar along the rib, indicating that it was used as filler between the seal and the rib. Unburned paper material was also found imbedded in the cured mortar between the seal and the rib. Paper was found in some joints between Omega blocks. The dimensions of two of the ten seal locations exceeded the maximum approved dimensions of 8 feet high and 20 feet wide. One seal was not set back at least 10 feet from the corner of the pillar.

After removal of remaining portions of Omega block from the floor, a layer of dry BlocBond material was evident. It appeared to be BlocBond that was spread on the floor dry and not BlocBond that had been mixed with water. Vertical joints were not coated with at least a ¼-inch thick application of BlocBond. Mortar was applied to the top horizontal surface and was spread by hand. Most of the mortar reaching the vertical joints was forced in by hand. During the underground investigation and, subsequently, during laboratory examination and testing, the limited extent of vertical joint mortar was noted as shown above in Figure 19. A center plank was not always incorporated into the top of the seal. The planks were not wedged properly, as required by the ventilation plan. In some cases, these planks did not extend from rib to rib. The space between planks and the space between wedges was not completely filled with BlocBond. In addition, wedges were sometimes driven between the Omega block and the wood plank. This forced the wedge into the Omega block rather than allowing the load to be more evenly distributed across the top of the seal. Wedges were also driven parallel to the wood planks rather than perpendicular, as shown in the approved plan. Although each wood plank would be completely wedged,

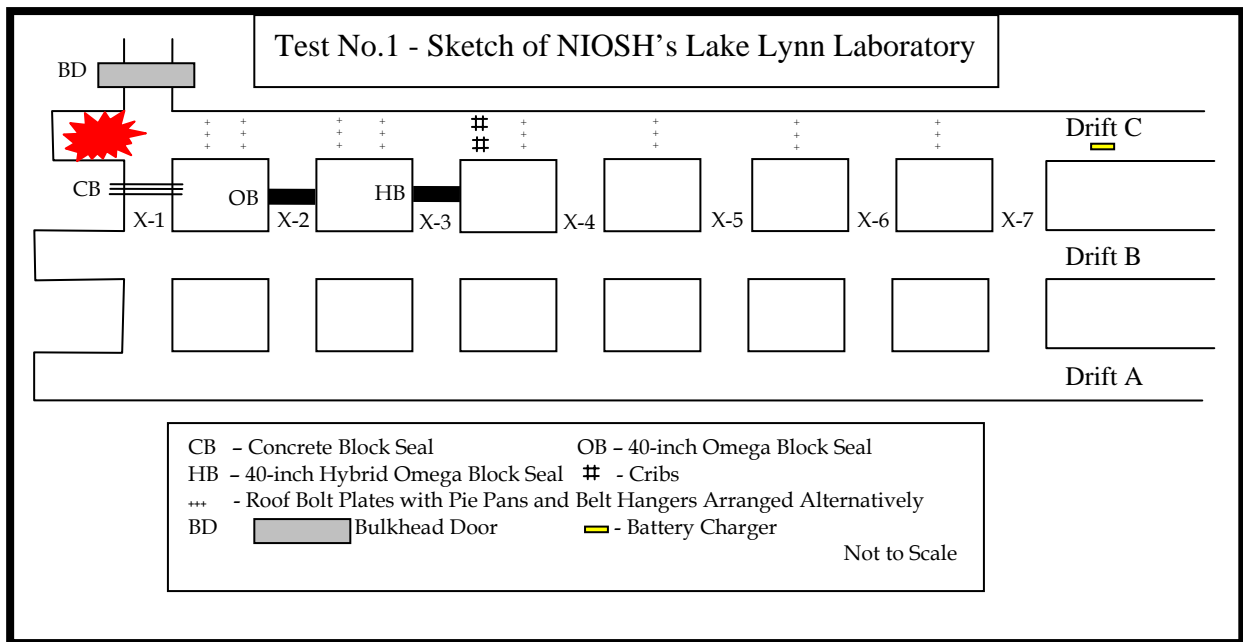
the wedges were placed skin-to-skin, which caused wedges to replace mortar. This procedure may have affected the strength of the seal.

### **Seal Testing**

Due to these differences in the method of construction, MSHA requested NIOSH assistance in evaluating the explosion resistance of various Omega block seal designs. As a part of this investigation, all seals were constructed at Lake Lynn. The purpose of this testing was to establish whether any detrimental effects resulted from the differences in construction and to establish the magnitude of pressures that may have occurred during the explosion at Sago Mine. This was the first time that seals had been subjected to full-scale test explosions generating total pressures on the seals, and the first time tests were conducted within a completely sealed area. An executive summary titled "Experimental Study of the Effect of LLEM Explosions on Various Seals and Other Structures and Objects" is contained in Appendix X.

Prior to the first test explosion, two 40 inch thick Omega block seals were constructed underground. A typical solid concrete block seal was constructed in No. 1 Crosscut. The Omega block seal in No. 2 Crosscut was constructed in the same manner as the one which successfully passed explosion testing in 2001. The Omega block seal constructed in No. 3 Crosscut incorporated several changes in the method of construction. These changes include applying unmixed mortar on the mine floor, not applying mortar directly to the vertical joints of the first course of blocks, and modifying the installation of wood planks and wedges between the last course of the Omega blocks and the mine roof. This second Omega seal, referred to as a hybrid seal, was not intended to accurately represent the seals that were destroyed at the Sago Mine. The seals were cured for 22 days. This represented the shortest curing period for any portion of the ten 2 North Mains seals. Two cribs were constructed in the entry just outby the No. 3 Crosscut. Belt hangers, roof plates, and roof bolt bearing plates were installed along the entry. A battery charger, removed from the Sago Mine, was located in the entry in which the explosion occurred.

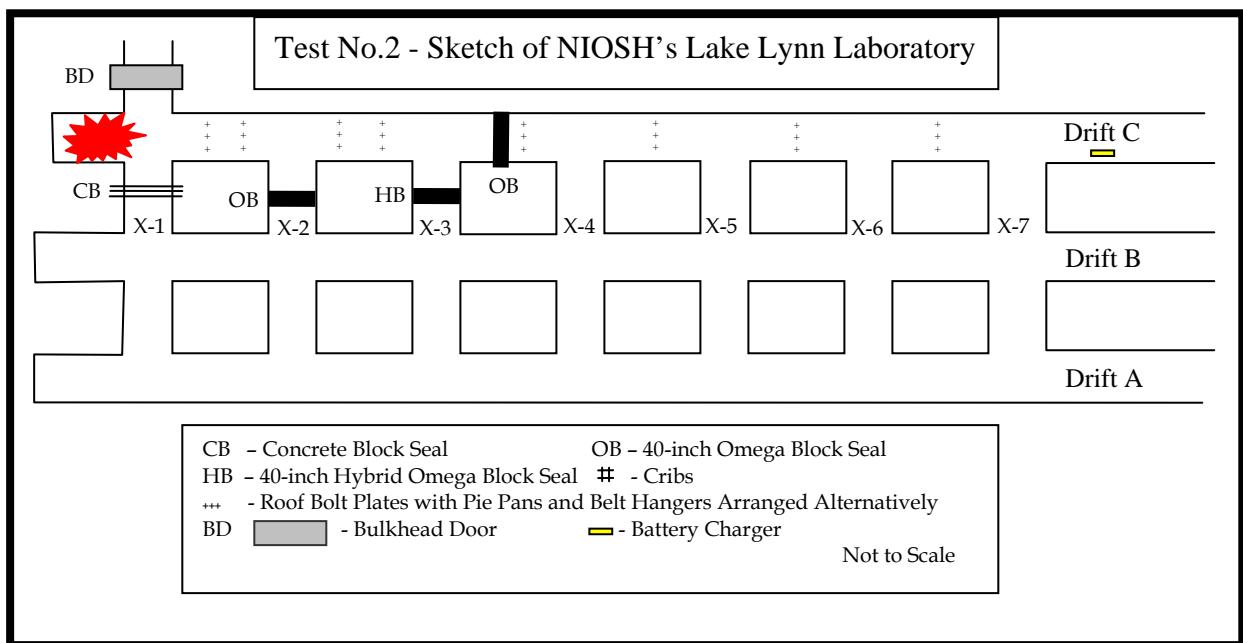
The first test explosion was conducted on April 15, 2006 and generated a static pressure pulse of about 23 psi on the seal in No. 2 Crosscut, and 25 psi on the seal in No. 3 Crosscut. Each of the three seals successfully withstood the pressure pulse. The battery charger was moved outby by a distance of at least 21 feet as a result of this explosion. The crib blocks were blown a maximum distance of about 883 feet from their initial location as a result of this explosion. Figure 30 is a sketch of the Lake Lynn Mine layout for Test No. 1.



**Figure 30 - Test No. 1 Lake Lynn Mine Layout**

For the second test explosion, the solid concrete block seal and both of the Omega block seals from the previous test remained in place. In addition, a 40 inch thick Omega block seal was constructed in the Drift C outby No. 3 Crosscut. This third Omega block seal was constructed in the same manner as the one which successfully passed explosion testing in 2001. The construction of this third seal across the drift effectively sealed off the inby area. The seals cured for 28 days. No cribs were constructed as part of this test. All damaged roof plates, and roof bolt bearing plates were replaced. The explosion was initiated in the sealed area. The purpose of this test was to impact the seals in the crosscuts with a static pressure pulse and the seal in the drift with a total pressure pulse from the explosion.

The explosion generated a pressure of 22 psi on the seal in No. 2 Crosscut, 39 psi on the seal in No. 3 Crosscut, and 51 psi on the seal constructed in Drift C. The test was conducted on June 15, 2006. The solid concrete block seal and the Omega block seal in No. 2 Crosscut successfully withstood the pressure pulse. The Omega block seals in No. 3 Crosscut and in Drift C were destroyed. The battery charger was moved outby by a distance of at least 79 feet as a result of this explosion. The greatest distance that seal debris was thrown as a result of this explosion was about 822 feet. Figure 31 is a sketch of the Lake Lynn Mine layout for Test No. 2.

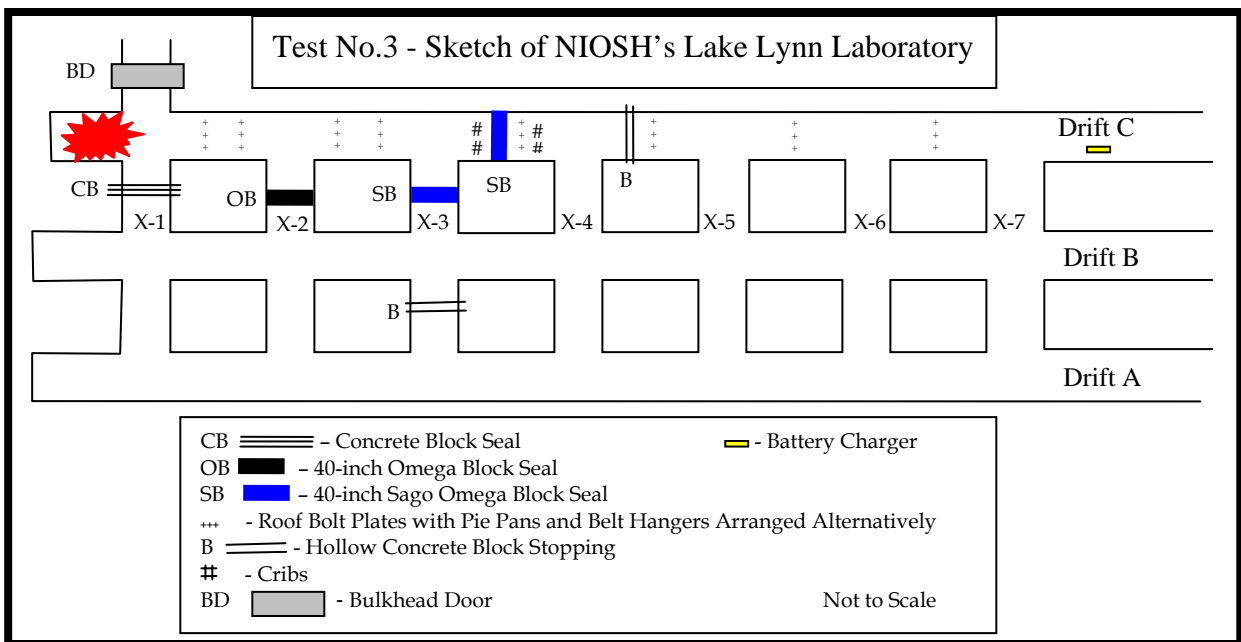


**Figure 31 – Test No. 2 Lake Lynn Mine Layout**

For the third test explosion, the solid concrete block seal and the Omega block seal in No. 2 Crosscut remained in place. Omega block seals that were similar to those constructed at Sago Mine were constructed in No. 3 Crosscut and in Drift C just outby No. 3 Crosscut. These Omega block seals incorporated several changes in the method of construction. These changes include; applying unmixed mortar on the mine floor, not applying mortar directly to any vertical

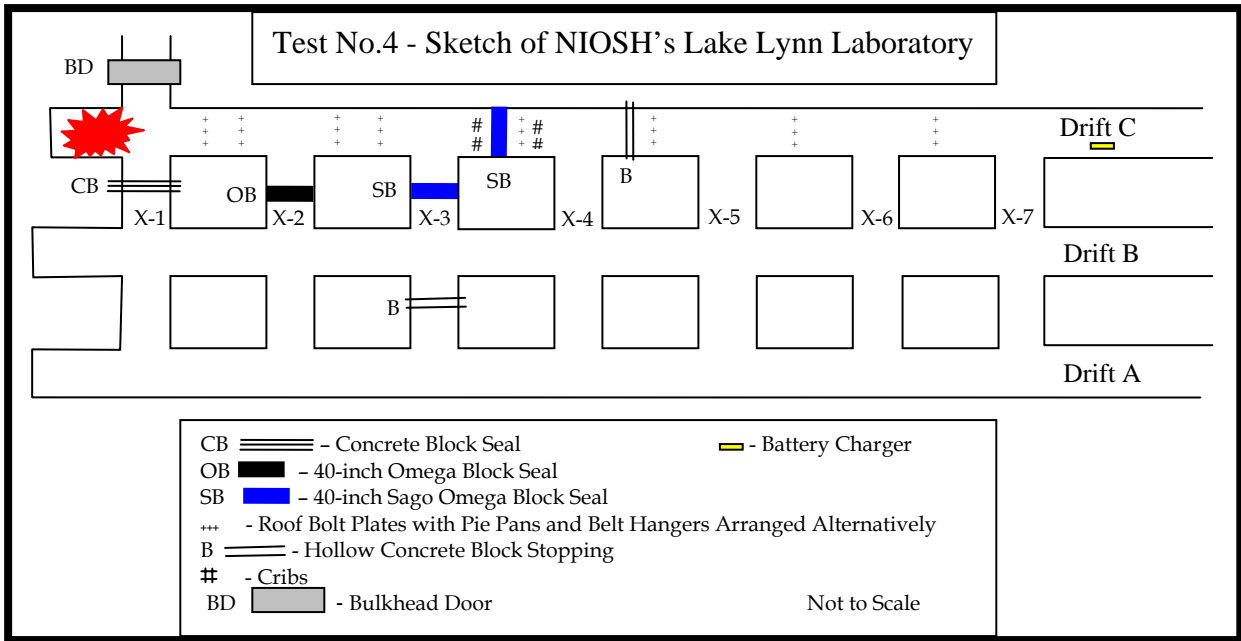
joints, and modifying the installation of wood planks and wedges between the last course of the Omega blocks and the mine roof. The construction of this third seal across the drift effectively sealed off the inby area. One dry-stacked stopping was constructed just outby the seal in the drift and one dry-stacked stopping was constructed in No. 3 Crosscut, behind the seal. Two cribs were built on both the inby and outby side of the seal in the drift. All damaged roof plates, and roof bolt bearing plates were replaced. The seals cured for 28 days. The explosion was initiated in the sealed area.

The purpose of this test was to impact the seals in the crosscuts with a static pressure pulse and the seal in the drift with a total pressure pulse from the explosion. The explosion generated a pressure of 13 psi on the seal in No. 2 Crosscut, 16 psi on the seal in No. 3 Crosscut, and 17 psi on the seal constructed in Drift C. The test was conducted on August 4, 2006. Each of the four seals successfully withstood the pressure pulse. Figure 32 is a sketch of the Lake Lynn Mine layout for Test No. 3.



**Figure 32 - Test No. 3 Lake Lynn Mine Layout**

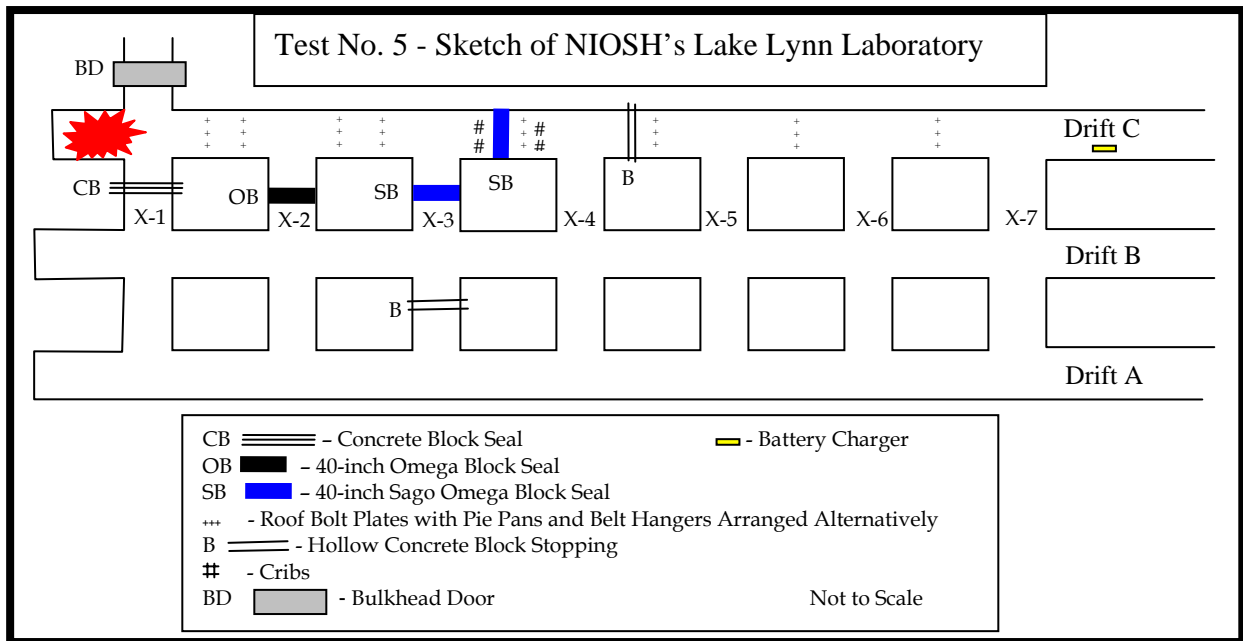
For the fourth test explosion, the four seals from the previous test remained in place. The fourth test was designed to increase the static and total pressures. The explosion was initiated in the sealed area. The explosion generated a pressure of 15 psi on the seal in No. 2 Crosscut, 18 psi on the seal in No. 3 Crosscut, and 21 psi on the seal constructed in Drift C. The test was conducted on August 16, 2006. Each of the four seals successfully withstood the pressure pulse. Figure 33 is a sketch of the Lake Lynn Mine layout for Test No. 4.



**Figure 33 - Test No. 4 Lake Lynn Mine Layout**

For the fifth test explosion, the four seals from the previous test remained in place. The fifth test was designed to significantly increase the static and total pressures. The explosion was initiated in the sealed area. The explosion generated a pressure of 26 psi on the seal in No. 2 Crosscut, 35 psi on the seal in No. 3 Crosscut, and 57 psi on the seal constructed in Drift C. The test was conducted on August 23, 2006. The solid concrete block seal and the Omega block seal constructed in No. 2 Crosscut successfully withstood the pressure pulse. Both of the Omega block seals that were similar to those constructed at Sago Mine were destroyed by the pressure pulse. The battery charger was

moved outby by a distance of about 30 feet as a result of this explosion. The crib blocks were blown a maximum distance of about 438 feet as a result of this explosion. Figure 34 is a sketch of the Lake Lynn Mine layout for Test No. 5.

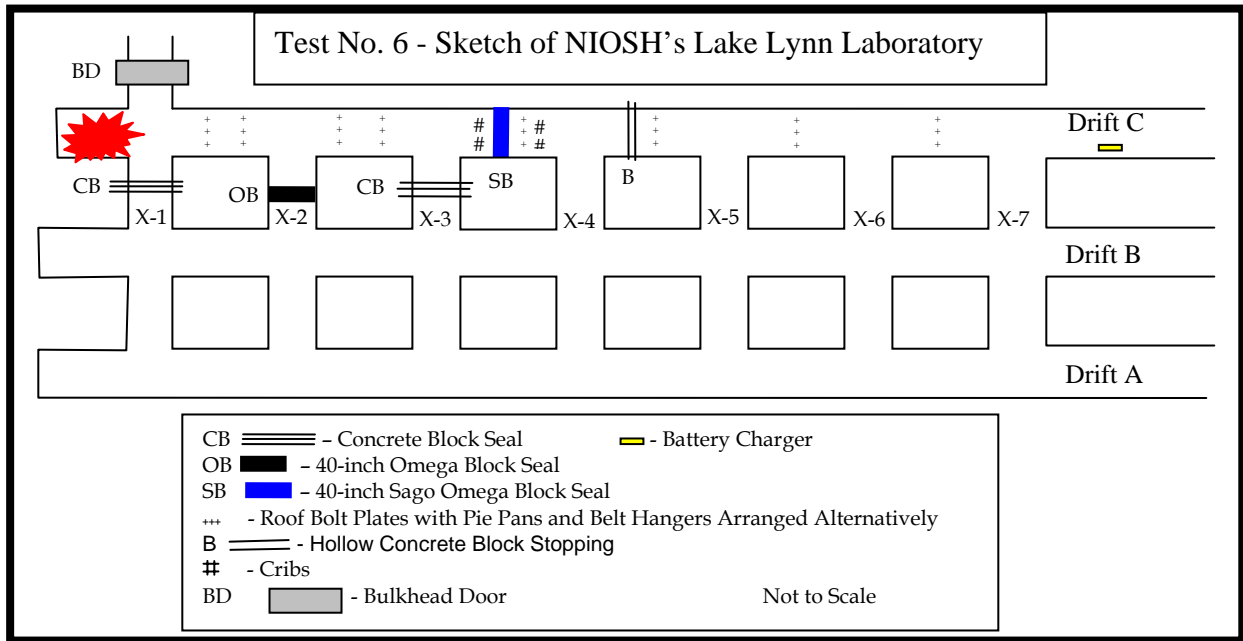


**Figure 34 - Test No. 5 Lake Lynn Mine Layout**

For the sixth test explosion, the solid concrete block seal and the Omega block seal in No. 2 Crosscut remained in place. A solid concrete block seal was constructed in No. 3 Crosscut and a seal constructed of Omega blocks from the Sago Mine was constructed in Drift C. The sixth test was designed to significantly increase the static and total pressures. The seals cured for 28 days. Two cribs were built on both the inby and outby side of the seal in the drift. One dry-stacked stopping was constructed in No. 3 Crosscut, behind the seal. The explosion was initiated in the sealed area. The explosion generated a pressure of 51 psi on the seal in No. 2 Crosscut, 49 psi on the seal in No. 3 Crosscut, and 93 psi on the seal constructed in Drift C. The test was conducted on October 19, 2006. Both of the solid block seals successfully withstood the pressure pulse. The Omega block seal in No. 2 Crosscut withstood the pressure pulse. The Omega block seal constructed in Drift C was destroyed by the explosion.



The greatest distance that seal debris was thrown as a result of this explosion was about 918 feet. The battery charger was moved outby by a distance of about 356 feet as a result of this explosion. The greatest distance stopping debris was thrown, as a result of this explosion, was about 748 feet. Figure 35 is a sketch of the Lake Lynn Mine layout for Test No. 6.



**Figure 35 - Test No. 6 Lake Lynn Mine Layout**

The belt hangers were intended to simulate those belt hangers that were installed in the Sago Mine at the time of the explosion. When any belt hanger displayed damage during a test, it was replaced with a new belt hanger prior to the next explosion test. Maximum explosion pressures ranged from 17 psi to 93 psi. One belt hanger, located 403 feet outby from the explosion origin, was significantly bent in test No. 5 and No. 6. The damage was most likely caused from projectiles, such as crib blocks, striking it. Inby belt hangers were not damaged even though they were exposed to higher pressures. From these tests, it does not appear that significant damage to belt hangers can occur at pressures less than 93 psi.

The test explosions have shown that solid concrete block seals can successfully withstand static explosion pressures of at least 49 psi. The Omega block seal that was constructed in the same manner as the one which successfully passed explosion testing in 2001 can successfully withstand static explosion pressures of at least 50 psi. Omega block seals constructed in a manner similar to those that were built prior to the January 2, 2006 explosion at Sago Mine can successfully withstand total explosion pressures of at least 21 psi. The Lake Lynn testing did not result in the same level of damage to the seals as observed at the Sago Mine.

## Electrical Power and Equipment

### Electrical Power System

The Allegheny Power Company supplied 138,000 volt alternating current (vac) electric power to the French Creek Substation, located approximately two miles from the mine, where it was reduced to a 12,470 vac solidly grounded system.<sup>36</sup> The power circuit supplied two high-voltage circuit breakers installed in a fenced area adjacent to the French Creek Substation. The 12,470 vac was transmitted through surface transmission lines to a branch transmission line. The branch line had visible disconnects at its first pole and lightning arresters were installed at the next pole. This branch line extended to the Sago Mine substation. This circuit was protected by a high-voltage circuit breaker, visible disconnects, and lightning arresters. A spare circuit breaker was installed in the same fenced area and was not in use. Each circuit breaker contained relays designed to provide overcurrent, short circuit and grounded phase protection.

Three 1,250 kva transformers located in the mine substation reduced the 12,470 vac to a 7,200 vac resistance grounded system<sup>37</sup> for underground distribution. A high-voltage circuit breaker, visible disconnects, and lightning arresters located in the surface substation provided circuit protection for the underground distribution system. The circuit breaker contained relays designed to provide overcurrent, short circuit, grounded phase, under-voltage, and ground monitor protection. The power circuit was provided with visible disconnects and lightning arresters at the mine openings where it entered the underground area of the mine via a 4/0 American Wire Gauge (AWG) high-voltage cable. All connections between underground power centers were made with 4/0 AWG mine power, ground, ground check, 8 kilovolt (kv) rated high-voltage cable. The power circuit was further reduced by underground transformers to 995 vac, 575 vac, 480 vac, and 240/120 vac for use by underground electric equipment.

The 12,470 vac was also reduced to 4,160 vac by three 167 kva pole-mounted transformers for the surface fan. The power circuit was provided with visible disconnects, fuses and lightning arresters. Three 100 kva pole-mounted transformers reduced the 12,470 vac to 480 vac and 240/120 vac for the surface electric equipment and mine facilities.

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<sup>36</sup> A solidly grounded system is one that has the neutral of the transformer electrically connected to the grounding medium without any intentional impedance. The grounding medium is usually earth or something serving as earth.

<sup>37</sup> A resistance grounded system is one that has the neutral of the transformer electrically connected to the grounding medium through a resistor. The purpose of the resistor is to limit the amount of current and voltage during a fault condition.

Power centers were located throughout the mine to reduce the voltage for use by the conveyor belt system, water pumps, battery chargers, trickle rock dusters, AMS, trolley communication system, underground workshop, outby work area lighting, the 1st Left section and 2nd Left Parallel section equipment and other miscellaneous equipment.

The mine incorporated three splitters, or switchhouses, into its power distribution system. A splitter contains a disconnect switch and a circuit breaker. It can contain more than one set of protective devices. It is used to establish branch circuits that may be de-energized independently of the main circuit. Maps of the electrical system, equipment, and associated items are shown in Appendices Y-1 and Y-2.

The high-voltage cable was damaged by the explosion near the mouth of 1st Left and 2nd Left Parallel. This caused the circuit breaker in the single splitter, located at 21 Crosscut, No. 1 Belt to de-energize the high-voltage circuit. Only the circuits outby the splitter remained energized such as the Nos. 1 and 2 Belt drives. The surface power remained energized as well.

## **Grounding Systems**

The Allegheny Power Company established a safety ground system<sup>38</sup> for the French Creek Substation. Two grounded neutral conductors were installed above the power conductors from French Creek to the branch circuit leading to the mine substation. One neutral conductor was continued from the branch circuit to the mine substation. This conductor was installed below the power conductors and connected to the safety ground system for the mine substation and surface electric equipment.

A second safety ground system was installed at the mine site. This safety ground system was separated from other safety ground systems by more than 25 feet. Its purpose was to establish a resistance grounding system for the underground power system and equipment.

The lightning arresters at this mine were also connected to ground fields. The lightning arresters located within the substation were connected to the surface safety ground system. The lightning arresters at the mine drift opening used for the underground power were connected to a separate ground field. A separate ground field was established for the lightning arresters protecting the AMS.

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<sup>38</sup> A safety ground system is designed to limit step and touch potentials between grounded components during a fault condition. Part of the safety ground system is the grounding medium (ground field).

A lightning arrester is a device that limits the overvoltage of lightning or other electrical surges by providing an electrical path between an ungrounded conductor and earth which is used as the grounding medium. A simple lightning arrester consists of two contacts that are separated by an air gap. One contact is connected to the transmission line and the other is connected to earth. The normal voltage of the circuit cannot bridge the gap. When an overvoltage occurs it sparks over the gap between the contacts. This creates an electrical path for the excess energy to discharge to earth.

### **Abandoned Pump in 2nd Left Mains Sealed Area**

The mine operator abandoned a submersible pump, its controller and a No. 6 AWG, 2,000 Volt cable with a male cable coupler in the 2nd Left Mains area. The pump and its components are shown in Appendix Y-2, "Electrical Map, 2nd Left Mains, 2 North Mains Inby Crosscut 57." The label on the pump indicated it was 8.1 horsepower with 10.2 full load amperage and it requires 575 vac, three phase power. The pump, controller, and several hundred feet of cable, located in the No. 6 entry, were under water at the time of the explosion. The majority of the cable was along the No. 5 entry with the coupler near survey station 4028. Portions of the cable were found hung on the ribs and roof near the controller and pump but the majority of it was found on the mine floor. The cable was approximately 1,300 feet long and was found in four sections.

### **Personal Equipment**

Twelve miner cap lamps were recovered from the barricade on 2nd Left Parallel section and submitted to A&CC for evaluation and testing. The report from A&CC concluded that there were no signs of a short circuit in any of the cap lamp assemblies which would be the source of a spark ignition in a methane-air atmosphere. Further, based on the results of previous testing during the approval process of the Koehler 5000 Series battery, the batteries were incapable of igniting a methane-air atmosphere due to arcing caused by a short circuit of the battery voltage. There were no signs of overheating in any of the cap lamp assemblies which would be the source of a thermal ignition in a methane-air atmosphere. All of the cap lamp bulb envelopes were intact with no exposed filaments. Therefore, no thermal ignition in a methane-air atmosphere could have been initiated by a hot filament. All of the bulbs were labeled with part numbers which were previously accepted and tested. Further, based on the results of previous testing during the approval process, the bulbs were incapable of igniting coal dust on the lens surface or a methane-air atmosphere inside the headpiece. All but one of the cap lamp assemblies illuminated correctly. Exhibit KLH-8 illuminated intermittently. Several discrepancies were identified, but none were considered to be an ignition hazard. The complete report is titled

Laboratory Inspection of Twelve Cap Lamps Recovered from a Mine Explosion at Wolf Run Mining Company's Sago Mine, I.D. No. 46-08791, PAR 92104.

Three Motorola non-permissible handheld radios were recovered from the barricade on 2nd Left Parallel section and two Motorola non-permissible handheld radios were recovered from the 1st Left crew. These handheld radios were submitted to A&CC for evaluation and testing. The Motorola PR400 radio is not MSHA approved for use in permissible areas of underground coal mines, but is approved by Factory Mutual (FM) as Intrinsically Safe for use in above ground explosive atmospheres, including methane-air mixtures. MSHA does not accept the FM approval in lieu of an MSHA approval.

The functionality of the radios were compared with two new Motorola PR400 radios and functioned as well above ground as the new units did. None of the radios exhibited visual signs that the radio produced a spark or thermal ignition source for the ignition of coal dust or methane-air mixture.

Information obtained through the A&CC's Emergency Communications and Tracking System Committee indicates that radios operating in the UHF band communicate an approximate maximum distance of 1500 feet within the same entry, with severely limited propagation around corners. This is highly dependent on coal seam height, entry geometry, and infrastructure within the entry. See "Executive Summary of Investigation of the Motorola Two-way Radios" in Appendix U.

The methane detectors carried by the miners on the 2nd Left Parallel section were recovered and tested. Jesse Jones, Ware, and Winans had CSE Model 102LD portable methane detectors. They were capable of measuring methane concentrations from 0% to 5% and did not have datalogging capability. Two of the three CSE Model 102LD portable methane detectors did not respond to methane within acceptable limits before calibration. After calibration, all three methane detectors responded to methane within acceptable limits.

Helms and Martin Toler had Industrial Scientific Model LTX310 portable multi-gas detectors. They were capable of measuring methane from 0% to 5%, CO from 0 to 999 ppm, and oxygen from 0% to 30% and had datalogging capability. The ISC Model LTX310 that belonged to Helms did not respond to methane and CO within acceptable limits before or after calibration. A bump test of the instrument indicated that the concentrations displayed on the LTX310 for methane was 12% too high while the CO display indicated a 400% higher level. The response to oxygen was not available after it was initially turned on because the oxygen reading went blank and remained blank for the duration of the tests. The memory captures and records the peak methane and CO values and minimum oxygen levels to which the instrument was exposed. It does not

indicate when that exposure occurred. The peak values reported before calibration for methane was 1.7% and for CO was 59 ppm. These values appear to be very similar to a calibration gas mixture. These recorded values indicate that the instrument was probably not on at the time of the explosion.

The ISC Model LTX310 assigned to Martin Toler did not respond to methane and CO within acceptable limits before calibration. It did respond to oxygen within acceptable limits before calibration. A bump test of the instrument indicated that the concentrations displayed on the LTX310 for methane was 45% too low while the CO display indicated a 200% higher level. After calibration, it responded to all three gases within acceptable limits. The memory captured and recorded the peak methane and CO values and minimum oxygen levels to which the instrument was exposed. It did not indicate when that exposure occurred. The peak values reported before calibration for methane was OR (Over Range), for CO was OR, and for oxygen was 14.6%. These recorded values indicate the instrument probably was on after the explosion and may indicate the concentration of the gases to which the miners may have been exposed, methane and CO greater than 5% and 999 ppm, respectively. The executive summary of the portable gas detector testing is contained in Appendix Z.

### **Potential Ignition Sources**

An atmosphere containing between 5% and 15% methane and over 12% oxygen can be an explosive mixture. The temperature required to ignite an explosive methane-air mixture is approximately 1,000 degrees F. An explosive mixture is easily ignited by an electrical arc, frictional spark, heated surface or open flame. The amount of energy necessary for ignition will vary with gas concentration, however, as little as 0.3 millijoule of electrical energy is required. This is equivalent to about 1/50 of the static electricity accumulated by an average sized man walking on a carpeted floor on a dry day. The average lightning strike has well over one billion millijoules of energy. Potential ignition sources for the explosion in the sealed area were evaluated, including lightning and roof falls. Other sources, including cutting and welding, mining operations, smoking and spontaneous combustion were considered but were eliminated as potential ignition sources for this explosion. This is discussed below.

### **Other Sources**

Electric circuits, cables and equipment were examined for evidence that they may have provided the ignition source for the explosion. Physical evidence and testimony indicated that some circuits and equipment were not energized prior to the explosion.

There was no evidence that the ignition source originated from the mine's underground electrical circuits, cables or equipment in the active portion of the mine. This includes the power system, conveyor belt system, water pumps, battery chargers, welders, mantrips, locomotives, rock dusters, AMS, the pager phones, trolleyphone system, radios, gas detectors, cap lamps, electric equipment contained in the underground workshop, outby work area lighting, electric doors and the 1st Left and 2nd Left Parallel section equipment.

Several additional ignition sources were considered as potential ignition sources for the explosion. These ignition sources include: the operation of cutting and welding torches, mining operations, smoking, and spontaneous combustion. Each of these ignition sources were initially considered but were eventually dismissed. There were no cutting and welding operations on-going in or near the sealed area at the time of the explosion. Mining operations were not occurring within close proximity to the 2 North Main seals. There was no person near the sealed area at the time of the explosion. Additionally, there were no smoking articles found during the investigation. The mine had no history of spontaneous combustion and there was no evidence of spontaneous combustion found during the investigation.

## **Roof Falls**

Roof falls can ignite explosive methane-air mixtures either by generating frictional heat or by releasing piezoelectric energy. During a roof fall, rocks forming the strata comprising the immediate and the main roof rub against one another as the roof breaks and falls. In rare cases, the resulting friction from rubbing or from impact can cause temperatures above the ignition temperature of methane. The USBM has conducted rubbing friction and impact friction experiments. Under carefully controlled laboratory experiments, the USBM was only able to ignite methane-air mixtures in a small percentage of tests, even when the methane concentration was optimum for ignition.

An ignition can also be generated by piezoelectric discharges during certain roof falls. This type of event is typically associated with rock containing crystalline structures such as tourmaline, quartz, topaz and Rochelle salt. These crystals produce electric charges on parts of their surface when they are compressed in particular directions. In coal mining, the most notable crystal formation found is the quartz content of sandstone. See "Evaluation of Potential for a Roof Fall to Ignite a Methane-Air Mixture" contained in Appendix O.

Although a roof fall cannot be definitively excluded as a potential ignition source, it is a highly unlikely source for the following reasons:

- Seven roof falls were located within the sealed area. Prior to the explosion, three pre-sealing roof falls had been identified on the mine map. During the investigation, it was observed that these three pre-existing falls had extended. Also four additional roof falls were observed that were not shown on the mine map prior to seal completion. See drawing in Appendix O. It is not known exactly when these four roof falls occurred. These four additional roof falls were located approximately 200 to 600 feet from the center of the origin of the explosion. Of these seven falls, the rubble and exposed fall cavity of the five closest roof falls within 440 feet were inspected. Access to the two roof falls beyond 450 feet was obstructed by deep water in the bottom mined areas.
- Shale is the predominant rock type visible in the roof fall rubble. Specifically, the material referred to as shale was classified as “laminated siltstone” with low quartz content in a soft matrix that inhibits quartz grain-to-grain contact. This low quartz rock type was not as conducive to frictional heating or piezoelectric sparking as sandstones that have been suspected as ignition sources in roof falls. The roof falls extended 7 to 12 feet above the mining horizon. Three roof fall cavities (see Appendix O) had sandstone beds exposed at the top of the fall rubble roughly 8 to 12 feet into the immediate roof above the underlying shale. The samples collected from the roof fall rubble were a variety of sandstone that was micaceous, and characterized by thin, alternating laminations of fine sand, silt, and mica partings. In contrast, the sandstones associated with piezoelectric sparking and rock-on-rock frictional heating are commonly considered to be dominated by quartz, exhibit stronger cementing or even quartz grain fusing (i.e. the metamorphic rock “quartzite”), and occur in more massive beds. Furthermore, the roof falls observed were outside the area where the explosion originated. Thus, rock-on-rock or piezoelectric ignitions are unlikely ignition sources.
- The only metal roof supports noted in the fall rubble were fully grouted bolts and the wire mesh noted under the rubble of one fall. These steel roof support materials have not been associated with ignitions in experiments or in documented observations of gob ignitions. It was not possible to determine whether cable bolts noted near the roof falls were in the fall rubble. However, previous laboratory testing of the sparks from cable bolt failure did not ignite methane-air explosive mixtures.
- Since there were no roof falls in the proximity of the origin of the explosion, wicking of methane from the roof falls to the origin was considered. Methane is lighter than air and is released into the mine atmosphere in concentrations generally in excess of 80%. Layering of methane can occur in a mine atmosphere where the velocity of the airflow is minimal and not sufficient to generate turbulence in the airflow. Upon ignition, the layer may burn without the generation of forces and without



generating turbulence in the mine atmosphere, commonly known as wicking. For wicking to occur, a methane layer must be continuous, within its explosive range of 5% to 15%, and would generally be located near the roof. The burning methane layer may eventually contact a larger accumulation, resulting in an explosion. However, a roof fall generates turbulence in the mine atmosphere mixing layers that may have been present. Additionally, the distance, elevation, and uneven roof conditions from the observed falls to the origin of this explosion make this highly unlikely.

- Computer simulations have predicted that air temperature could increase rapidly to the point of igniting methane or coal dust during a roof fall. The area was sealed, wet, and without air movement, so that any existing coal dust could not have been suspended. The roof falls observed in the 2 North Mains seal area that were not noted on the mine map prior to sealing were too small to ignite methane by compression.

## Lightning Overview

Lightning is an electrostatic discharge (the same kind of electricity that can deliver a shock when touching a doorknob) between a cloud and the ground, between clouds, or within a cloud. Lightning is mostly associated with thunderstorms but is also created during volcanic eruptions, dust storms, forest fires and tornados.<sup>39</sup>

Nearly 1,800 thunderstorms occur at any moment around the world and lightning strikes the earth 100 times per second.<sup>40</sup> Lightning occurs less frequently in the winter because there is not as much instability and moisture in the atmosphere as in the summer.<sup>41</sup> West Virginia experiences thunderstorm activity approximately 30-50 days per year.<sup>42</sup>

Thunderstorms have very turbulent environments. These environments include strong updrafts and downdrafts that occur often and close together. The updrafts carry small liquid water droplets from the lower regions of the storm to heights between 35,000 and 70,000 feet. At the same time, downdrafts are transporting hail and ice from the frozen upper parts of the storm. When these particles collide, the water droplets freeze and release heat. This heat keeps the

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39 [www.nssl.noaa.gov/primer/lightning/lrg\\_basics.html](http://www.nssl.noaa.gov/primer/lightning/lrg_basics.html).

40 [www.moncooem.org/thunderstorms.htm](http://www.moncooem.org/thunderstorms.htm).

41 [www.nssl.noaa.gov/primer/lightning/lrg\\_faqs.html](http://www.nssl.noaa.gov/primer/lightning/lrg_faqs.html).

42 [www.moncooem.org/thunderstorms.htm](http://www.moncooem.org/thunderstorms.htm).

surface of the hail and ice slightly warmer than its surrounding environment, and a soft hail, or graupel forms.

When graupel collides with additional water droplets and ice particles, a key process occurs involving electrical charge. Negatively charged electrons shear off of the rising particles and collect on the falling particles. The result is a storm cloud that is negatively charged at its base, and positively charged at the top. Opposite charges attract one another. As the positive and negative areas grow more distinct within the cloud, an electric field is created between the oppositely charged thunderstorm base and its top. The farther apart these regions are, the stronger the field and the stronger the attraction between the charges. The atmosphere is a very good insulator that inhibits electric flow. A huge amount of charge has to build up before the strength of the electric field overpowers the atmosphere's insulating properties. A current of electricity forces a path through the air until it encounters something that makes a good connection. The current is discharged as a strike of lightning. While all this is happening inside the storm, a positive charge begins to pool on the surface of the earth beneath the storm. This positive charge will shadow the storm wherever it goes, and is responsible for cloud to ground lightning.<sup>43</sup>

Most of these flashes originate near the lower-negative charge center of the storm and deliver a negatively charged lightning strike to Earth.<sup>44</sup> However, the electric field<sup>45</sup> within the storm is much stronger than the one between the storm base and the earth's surface, so about 75 to 80% of lightning occurs within the storm cloud.<sup>46</sup> The voltage of lightning discharges can range from 100 million to one billion volts.<sup>47</sup>

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43 [www.nssl.noaa.gov/primer/lightning/ltg\\_basics.html](http://www.nssl.noaa.gov/primer/lightning/ltg_basics.html).

44 [thunder.msfc.nasa.gov/primer/primer2.html](http://thunder.msfc.nasa.gov/primer/primer2.html).

45 An electric field is a field or force that exists in the space between two different potentials, such as between negatively and positively charged regions of a thunderstorm.

46 [www.srh.noaa.gov/mlb/ltgcenter/whatis.html](http://www.srh.noaa.gov/mlb/ltgcenter/whatis.html).

47 [www.nssl.noaa.gov/primer/lightning/ltg\\_faq.shtml](http://www.nssl.noaa.gov/primer/lightning/ltg_faq.shtml).



Cloud to ground lightning is defined as lightning that discharges to earth. This is shown in Figure 36.<sup>48</sup> These are negative discharges most of the time. Positive discharges account for less than 10% of all cloud to ground strikes, and most often occur on the periphery of a thunderstorm. The peak current of a positive discharge is often much larger than a negative one, resulting in greater potential for damage.<sup>49</sup>

**Figure 36 - Cloud to Ground Lightning**



Intra-cloud lightning occurs within separate charge centers of a cloud. This illuminates portions of the cloud without any visual evidence of the lightning strike that is occurring within the cloud.<sup>50</sup> This is shown in Figure 37.<sup>51</sup> The lightning discharge may be positive or negative depending on the charge center.

**Figure 37 - Intra-cloud Lightning**



Sometimes an intra-cloud discharge occurs between charge centers of different clouds. This results in a cloud to cloud discharge.<sup>52</sup> This is shown in Figure 38.<sup>53</sup>

**Figure 38 - Cloud to Cloud Lightning**

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48 [thunder.msfc.nasa.gov/primer/primer2.html](http://thunder.msfc.nasa.gov/primer/primer2.html).

49 [www.srh.noaa.gov/mlb/lbgcenter/whatis.html](http://www.srh.noaa.gov/mlb/lbgcenter/whatis.html).

50 [thunder.msfc.nasa.gov/primer/primer2.html](http://thunder.msfc.nasa.gov/primer/primer2.html).

51 [www.nssl.noaa.gov/primer/lightning/lbg\\_basics.html](http://www.nssl.noaa.gov/primer/lightning/lbg_basics.html).

52 [thunder.msfc.nasa.gov/primer/primer2.html](http://thunder.msfc.nasa.gov/primer/primer2.html).

53 [www.nssl.noaa.gov/primer/lightning/lbg\\_basics.html](http://www.nssl.noaa.gov/primer/lightning/lbg_basics.html).



Also, upward lightning has been known to occur. It is a discharge from a tall structure to a cloud. It develops from the pool of positive charge shadowing the storm.<sup>54</sup> This is shown in Figure 39.<sup>55</sup>

**Figure 39 - Upward Lightning**

In the past, lightning has been identified as a possible ignition source for explosions in sealed areas of underground coal mines. Prior to the Sago accident, MSHA had not conducted full underground investigations of post-explosion sealed areas, because hazardous conditions did not permit full exploration or investigation of these areas. Table 10 is a list of some of these occurrences.

**Table 10 - Mine Explosions in Sealed Areas with Lightning as a Possible Ignition Source**

Mine Name	Year Explosion Occurred	Metal Conduit Present	Number of Seals Destroyed
JWR No. 3	1986	Yes	Shaft cap
Mary Lee No. 1	1993	Yes	2 plus shaft cap
Oak Grove No. 1	1994	Yes	5
Beatrice	1994	Yes	Shaft cap
Gary 50	1995	Yes	None
Oak Grove	1996	Yes	1
Oasis No. 1	May, 1996	Yes	4
Oasis No. 1	June, 1996	Yes	4
Oak Grove	1997	Yes	3
Soldier Canyon	2000	Yes	Shaft cap
Pinnacle	2001	Yes	Shaft cap
Big Ridge	2002	Yes	1

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54 Upward Lightning Flashes, Wada, A., Miki, M., Asakawa, A., Central Research Institute of Electric Power Industry, Nagasaka, Japan (2004)

55www.rf-web.tamu.edu/about/

Lightning detection networks track lightning throughout the United States using sensors located at various locations. MSHA obtained reports from two lightning detection companies regarding lightning strikes near the mine on the morning of the explosion. See “Vaisala Group and AWS Convergence Technologies, Inc. Reports” contained in Appendix AA. The Vaisala Group tracked the lightning through the National Lightning Detection Network (NLDN). AWS Convergence Technologies, Inc. used the United States Precision Lightning Network (USPLN). USPLN is owned and operated by TOA Systems and Weather Decision Technologies.

As reported by the lightning detection companies, both of these lightning detection systems have limitations. The NLDN has an accuracy of 1,640 feet on average while the USPLN has an accuracy of 820 feet. Both systems require that at least three sensors detect the discharge before it is recorded. If less than three sensors detect a discharge, it will not be recorded as a strike. Also, upward lightning initiated by tall structures cannot be detected by these systems. The USPLN has a detection probability of 95% for cloud to ground lightning and 60% for intra-cloud lightning in the West Virginia region. The NLDN does not record cloud to cloud or intra-cloud discharges. It also has a detection probability between 80-90 percent. Therefore, unrecorded lightning discharges can occur during a storm along with the recorded discharges.



The NLDN recorded two lightning strikes near the mine area at the time of the accident. The first strike occurred at 6:26:35.522 a.m. and reportedly occurred more than one mile south of the mine drift openings. This was a positively charged strike with a magnitude of 38,800 amps. Several unsuccessful attempts were made to locate evidence of a strike in this area. The other lightning strike occurred at 6:26:35.680 a.m. and was about one mile north of the mine drift openings. It was also a positive lightning strike with a magnitude exceeding 100,000 amps. Evidence of this strike hitting a tree was found. The tree had freshly splintered pieces scattered around it. This is shown in Figure 40.

**Figure 40 - Damaged Tree**

USPLN recorded one lightning strike near the mine area at the time of the accident. The strike occurred at 6:26:35.522 a.m. and reportedly was about a half of a mile south of the drift openings. This was a positively charged strike with a magnitude of 35,000 amps. Several unsuccessful attempts were made to locate evidence of a strike in this area. A map contained in Appendix BB titled "Sago Mine in relation to recorded location of lightning strikes, a lightning - damaged poplar tree and the mine's phone and power lines" shows the three recorded lightning strikes.

### **Lightning as an Ignition Source**

The Virginia Polytechnic Institute and State University's Department of Geosciences concluded that a seismic event most likely occurred at or near the Sago Mine within a four-second interval centered at 06:26:38 a.m. on January 2, 2006. A copy of that report titled "Results from Analysis of Seismic Data..." is contained in Appendix CC. In addition, the atmospheric monitoring system recorded the first presence of CO at 06:26:35 a.m. The nearby lightning strikes recorded by NLDN and USPLN occurred at approximately the same time as the seismic event and the initial alarm for the AMS.

To determine if lightning energy may have entered the mine, MSHA contracted with Sandia Corporation, Sandia National Laboratories (Sandia). They performed modeling and testing to simulate whether lightning energy could enter the mine by direct contact or indirect inductive coupling. Sandia has unique capabilities to characterize and mitigate lightning effects on high value assets with the Department of Energy and other agencies as part of a national security mission in nuclear weapons stockpile stewardship. From November 5 through November 9, 2006, personnel from Sandia conducted direct and indirect tests at the mine site. They compared the energy levels recorded from these tests with the levels required to initiate an arc. Sandia also analyzed the raw data provided by two lightning detection databases for other lightning discharges that failed to meet detection standards. They failed to find evidence of another cloud to ground strike in the correct timeframe. The Sandia report concluded "that lightning-induced electrical arcing was not only plausible, but highly likely." See report titled "Measurements and Modeling of Transfer Functions for Lightning Coupling into the Sago Mine" contained in Appendix DD.

Based on this information, MSHA concluded that lightning is the most likely ignition source for this explosion. Several plausible lightning strike scenarios illustrate how significant energy could ignite methane in the sealed area of the Sago Mine. These were evaluated to determine the most likely possibility. Three scenarios for energy from lightning to enter the sealed area were evaluated and are listed below as A, B and C.

- A. A recorded strike occurred in the proximity of the mine, hitting a tree. Two apparent paths for energy from this recorded lightning strike to reach the portal are through 1) the telephone grounding system or 2) the high-voltage power system. Further evaluations were undertaken to determine if the energy from lightning could be transported from the portal to the sealed area.
- B. A lightning strike delivered from the surface area directly through a conductor over the sealed area, such as gas wells and their interconnected piping system or water in the strata overlying the sealed area.
- C. A lightning strike over the sealed area indirectly energizing metallic objects within the sealed area.

Scenario A - A recorded strike occurred in the proximity of the mine, hitting a tree. Two apparent paths for energy from this recorded lightning strike to reach the portal are through 1) the telephone grounding system or 2) the high-voltage power system. Further evaluations were undertaken to determine if the energy from lightning could be transported from the portal to the sealed area.

#### *1) Surface Telephone Grounding Conductor*

A resident living near the damaged tree stated that his telephone service was interrupted for two days after the lightning strike. An investigation of this area revealed that the strike hit the tree and left a hole in the ground at the base of the tree.

Investigators analyzed the area around the tree and found that an underground telephone communication cable was located approximately 40 feet from the tree. A telephone junction box was located approximately 100 feet from the tree. The communication cable was routed through junction boxes between the tree that was struck by lightning and the mine. Each junction box was connected to the earth by a ground electrode and was connected to the metallic shielding on the communication cable. The location of the tree struck by lightning along with the identified locations of each telephone pole and telephone junction box leading to the mine are shown in Appendix BB.

Earth resistance measurements were conducted at the tree near the mine, which was struck by lightning, and at a Verizon telephone junction box located approximately 40 feet from the tree. These measurements were taken to determine the soil resistivity. The earth resistance test from the tree to the Verizon junction box revealed an earth resistance value of 4.92 ohms when taken by the three pole method with the Lem Unilap NGI tester. Four additional earth resistance measurements were conducted at right angles from the tree with the Lem Unilap NGI tester. These four tests revealed an average low earth resistance of 4.82 ohms within a 60 feet diameter of the tree.

Resistance measurements were taken with a Fluke MegOhmMeter from the Verizon junction box to a power pole located at the supply trailer located on mine property. All grounds were connected common and to earth at the base of that pole. These measurements revealed the total resistance of the ground circuit for the telephone system from the junction box to the power pole was 204.8 ohms.

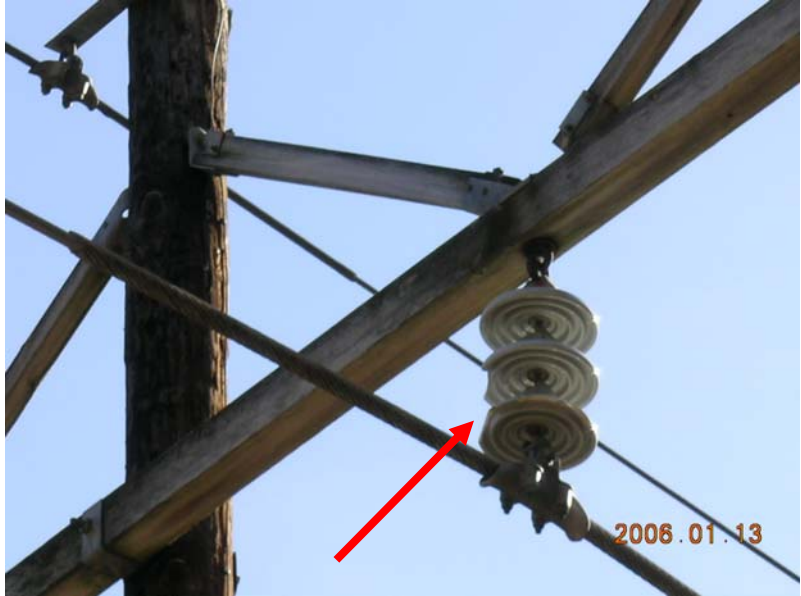
The telephone system and earth provided a low resistance path that extended from the junction box located near the tree struck by lightning to the mine. This path was also connected to the surface telephone system ground, the safety ground system for the surface equipment and the safety ground system for the underground mine electric power system. All of the installed grounding conductors, with the exception of the bathhouse and foremen's offices, were connected to the surface metal belt structure, mine track system and trolleyphone system.

## *2) High-Voltage Mine Power Electric System*

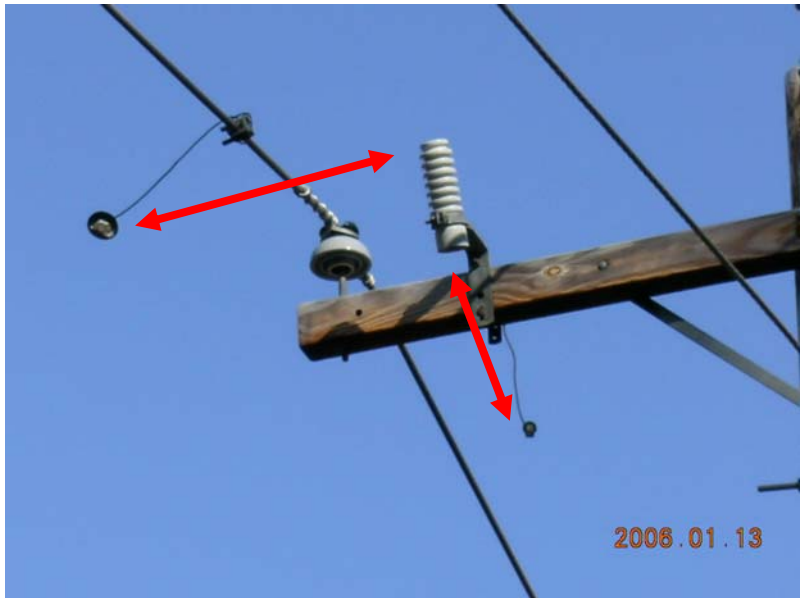
A lightning strike occurred in the proximity of high-voltage transmission lines near the mine, hitting the tree. The lines which extended from the French Creek Substation to the preparation plant and to the mine were examined. The purpose of this examination was to determine if lightning may have struck the main transmission or branch lines and entered the mine on one or more of the branch lines. The examination of the transmission line from the French Creek Substation and branch line that extends to the mine revealed damage to a phase insulator and a lightning arrester. The phase insulator was damaged on the main



transmission line. The lightning arrester was damaged at the second pole of the branch lines leading to the mine. A map showing the high-voltage transmission and branch lines is shown in Appendix BB. Figures 41 and 42 are photographs of the damaged insulator and lightning arrester below.



**Figure 41 - Damaged Insulator**



**Figure 42 - Damaged Lightning Arrester**

It was not possible to determine if the lightning storm that occurred on the day of the accident caused the damage to the lightning arrester and insulator. A previous storm or other event may have caused this damage.

Electric circuits and equipment were examined and tested on the surface and underground to determine if lightning entered the mine through one or more of the high-voltage power conductors. These examinations and tests revealed that none of the lightning arresters on mine property or the surge suppressors installed in the mine high-voltage power centers were damaged by lightning. There was no flash-over arcing or tracking identified that could be caused by lightning in the electric equipment installed on the surface at the mine or underground.

MSHA took electrical earth resistance measurements of the safety ground systems for the mine substation and the underground power system and equipment. These measurements were taken to determine if the grounding systems were of a low resistance value. The measurements were taken with a Lem Unilap NGI ground resistance tester. This device used the three-pole method to check resistance with the poles spaced at 20 foot intervals. The test of the safety ground system for the surface mine substation revealed that the system had a resistance value of 9.38 ohms. The test of the safety ground system for the underground power system and equipment revealed the system had a resistance value of 7.4 ohms. These measurements showed that both grounding systems had low resistance values. These systems provided an adequate means for dissipating electrical surges from system operation or other sources such as lightning.

Because a lightning strike occurred in proximity to the high-voltage transmission lines, an induced voltage could have occurred. When voltage is induced in transmission lines, it can affect the entire system. Induced voltages would have the potential to damage the transformers at either the French Creek or Sago substations due to direct current applied on an iron core transformer. If this had occurred, the French Creek substation would have detected a significant voltage increase and would have de-energized the entire system. Lightning arresters at the French Creek substation and at the mine should have dissipated this voltage. There was no interruption of electrical power at the mine, so any induced voltage on the high-voltage transmission lines was not significant.

However, the two grounded neutral lines above the transmission lines could have transmitted an induced voltage. These grounded neutral lines were connected to the surface safety ground. Therefore, an induced voltage could have been produced on the grounded neutral lines and transmitted to the surface safety ground which was also connected to the surface telephone system ground and the safety ground system for the underground mine electric power system. All of the installed grounding conductors, with the exception of the bathhouse and foremen's offices, were connected to the surface metal belt structure, mine track system and trolleyphone system.

### *Lightning Energy from the Portals to the Sealed Area*

The interconnection of the surface telephone system grounding conductor, surface lightning arrester grounding conductors, the continuous metal structure of the belt line, the mine track, and the surface and underground mine power system grounding conductors were common. Since they were common, they created a low resistance path for the energy from a lightning strike to possibly enter the mine, and extend to the No. 6 belt drive, which is approximately 400 feet from the 2 North Mains seals.

The grounding conductors for the belt starters and motors on all conveyor belts were connected to the frames of the starters, the belt drive motors, and the metal frames of each conveyor belt. The No. 6 belt drive for the 2nd Left Parallel was at 58 Crosscut, No. 4 Belt along with the No. 4 belt tailpiece. The conveyor belts were suspended from the mine roof by metal chains attached to brackets bolted to the roof. The belt drive and belt tailpiece were provided with metal guarding materials to minimize the likelihood of persons contacting moving parts. The metal guarding and the metal supports for the guarding were anchored firmly against the mine roof and in contact with the wire mesh installed on the roof.

The area where the ten seals were located prior to the accident had metal wire mesh installed against the roof in the Nos. 5, 6 and 7 entries of 2 North Mains, and in the Nos. 4, 5 and 7 entries in the 2nd Left Mains. The wire mesh assisted in controlling the effects of roof spalling and was installed rib to rib, overlapped with roof bolts and spider plates to hold it against the mine roof. The metallic bolts and spider plates attached the wire mesh against the roof firmly, and provided a good electrical connection throughout the wire mesh. The wire mesh was removed from the area of the roof immediately above the location of the seals. The mesh in the No. 5 entry (seal No. 6), the No. 6 entry (seal No. 7) and the No. 7 entry (seal No. 8) had gaps 10, 11 and 4 feet wide, respectively. There were gaps in the wire mesh in several other locations as well. Appendix Y-2, "Electrical Map, 2nd Left Mains, 2 North Mains Inby Crosscut 57" shows the wire mesh installed outby and inby the sealed area.

A 2 inch diameter, 40 foot long galvanized steel pipe was installed to provide a conduit for an air-sampling pipe through seal No. 10 in the No. 9 entry. The pipe extended into the sealed area and was supported on cribs. About three feet of the metal pipe extended from the seal on the active side, which was reduced to ½-inch diameter. A ½-inch diameter copper pipe was installed inside the steel pipe with a ball valve connected to the end of the copper pipe. The sampling pipe was located on the left side of the seal approximately 12 inches from the roof. Wire mesh was not installed in the No. 9 entry. This sampling pipe was not connected to a low resistance path. Therefore, the sampling pipe was not a likely path for lightning or any energy to reach the origin of the explosion.

Thirty-one earth resistance measurements of the mine roof and floor were taken. Measurements were taken from the end of the 2 North Mains track (survey station 3923) in the No. 6 entry to the origin of the explosion. The distance from the mine track to the origin is approximately 1,100 feet. A Lem Unilap NGI tester using the four-pole method was used. These earth resistance measurement values as well as the location of each previously installed seal, and the areas of the mine roof and floor where tests were conducted, are shown on the map titled "Earth Resistance Measurement Values" in Appendix KK. Measurements between these points revealed a low resistance path, so energy could flow easily between them.

Electrical earth resistance measurements were taken underground using the Lem Unilap NGI tester with the four-pole method. The results of the measurements are shown in Appendix KK. One series of tests was conducted at each location of the ten 2 North Mains Seals. Two other series of tests involved acquiring data in the belt and track entries to inby the 2 North Mains seals location. These measurements were taken to determine the resistivity of the path between these points. Three measurements were taken at each location. The four poles were attached to roof bolt plates during one test. Measurements were taken from metal pins that were installed in the mine roof. For the third test, the poles were installed in the mine floor. Measurements between these points revealed a low resistance path.

Measurements were also taken from the No. 6 Belt starter to various sites near survey station 4010 and No. 1, No. 2 and No. 9 seal areas. These measurements were taken to determine the resistivity between the points. A Megger resistance tester and a Beckman HD 110 multi-meter were used in conjunction with 2-12 AWG wires connected in parallel to obtain resistance readings. Measurements between these points revealed a low resistance path. The results of the resistivity measurements, including the locations of the measurements and the values, are shown in Appendix KK.

The underground mine power system grounding conductors, belt support structure, metallic guards, roof support and wire mesh were connected together. Measurements indicate that even with gaps in the wire mesh, a low resistance path continued from the No. 6 Belt drive into the sealed area.

Sandia conducted a direct drive test to determine if lightning energy could enter the mine through the low resistance path. They applied a test signal at the portal to the belt conveyor structure, trolley communication antenna, high-voltage cable grounding medium, and the track rail. They monitored the signal with current and voltage probes at several locations in the mine including where the mine belt structure, trolley communication line, and the track rail were closest to the 2 North Mains seals.

Resistivity measurements indicated that electrical energy could travel from the surface of the mine to the point of origin in the sealed area. However, Sandia concluded the energy is divided sufficiently by earth grounding so that only a relatively small amount of energy is directed into the mine near the sealed area. It is unlikely this method could provide an adequate amount of energy at the point of origin.

The ground wires in the high-voltage cable exhibited a relatively high current at the closest point to the 2nd Mains Seals. The high-voltage cable does not end at the 2nd Left Parallel switch, but continues to the 2nd Left Parallel section power center. Sandia analyzed the possibility that lightning energy on this portion of the high-voltage cable may have induced energy onto the abandoned pump cable in the sealed area. Sandia concluded that any energy induced on the pump cable would be too low to ignite methane. Energy induced onto the pump cable is discussed further in Scenario C.

Sandia further concluded that it is highly unlikely a 100,000 amperes lightning strike attached at the mine portal to the belt conveyor structure, trolley communication antenna, high-voltage cable grounding medium, and the track rail could generate sufficient voltage on the pump cable within the sealed area to initiate electrical arcing. Therefore, it is not likely that methods discussed in this scenario could ignite methane in the sealed area.

Scenario B – A lightning strike delivered from the surface area directly through a conductor over the sealed area, such as gas wells and their interconnected piping system or water in the strata overlying the sealed area.

#### *Direct Strike Over the Sealed Area*

Both lightning detection systems have limitations and do not record all lightning strikes. An unrecorded cloud to ground or an upward discharge may have occurred over the sealed area. Upward lightning may have been initiated from a nearby communications tower. Four towers are within about one mile of the sealed area, the closest one being about a half mile away. The lightning energy could have been delivered from the surface area directly through a conductor over the sealed area, such as gas wells and their interconnected piping system or water in the strata overlying the sealed area.

### *Gas Wells and Interconnected Metal Piping System*

Several gas wells and interconnecting metallic pipelines were installed in the vicinity of the mine. One gas well was located about a half mile northwest of the tree that was struck by lightning. A pipeline connected this well with other gas wells in the area, and extended approximately 2.4 miles to an active gas well (API# 47-097-01251) located near the previously mined sealed area in 2 North Mains. The well casing was not located in the sealed area itself. The location at the surface of the well indicates it may have been as close as 107 feet from the mine workings. The well extended from the surface and penetrated the coal seam at approximately 377 feet, extending approximately 4,755 feet deep to the natural gas reservoir. The well was encased with 10 feet of 13 inch diameter metal casing, 713 feet of 8 ¼ inch metal casing, and 4,032 feet of 4 ½ inch metal casing.

The metallic gas pipeline over the sealed portion of the mine where the explosion occurred was not tested due to liability concerns of all participants. If the pipeline is viewed as a conduit of energy and if it was installed as a continuous metallic structure, then it could conduct lightning energy. The cell towers that are in close proximity to the pipeline could have experienced a lightning strike or an upward-going positive strike that was not recorded by the lightning detection networks. The cell towers are well grounded to earth and therefore would conduct the lightning energy into earth and on to the pipeline. This could generate two results.

Result 1: The pipeline is not in direct contact with the surrounding earth and exhibits a high resistance contact with earth. In this case the pipeline would be looked upon as an insulated conductor that would conduct lightning energy. The lightning energy would be conducted to the gas well that the pipeline was connected to and then the lightning energy would be dissipated into the earth through the gas well casing. While the lightning current is flowing through the pipeline it will generate a similar electromagnetic pulse that a lightning strike would generate. This could then induce a voltage in the cable that was in the sealed area that could result in an electrical arc at the cable.

Result 2: The pipeline is in direct contact with the earth which is of low resistivity and therefore well connected to earth. Resistivity tests above the sealed area show that the immediate earth exhibits low resistance. In this case the lightning charge would dissipate very quickly into the surrounding earth as was shown by Sandia in their direct drive tests conducted on the track that entered the mine. The track, like the pipeline, was in direct contact with earth. Therefore, it is unlikely sufficient current to ignite methane would be able to enter the sealed area of the mine.

The first result does provide a possible explanation as to how lightning energy could have traveled on the surface to induce energy and a resultant arc in the cable left in the sealed area of the mine. Neither of these results would have by themselves provided a direct drive but could have enhanced the indirect drive to initiate an arc in the sealed area of the mine.

The investigators evaluated the possibility that energy from a direct lightning strike penetrated into the sealed area through the metal gas well casing and provided the energy to ignite methane. No visible evidence of the lightning strike to the metal well heads or gas lines was observed. Additionally, no damage to the ground was observed in the vicinity of the wells or along the length of buried metal lines. The only damage observed in the area was to a tree located near a buried metal gas line on a hilltop approximately 4,600 feet north of a recorded strike. When the tree was damaged is unknown, but neither of the lightning detection networks recorded a strike at this location. There was no evidence underground of the explosion originating in the entries nearest the gas well. Although wicking of a methane layer is possible, the distance, elevation, and uneven roof conditions from these entries to the origin make this unlikely. See Appendix GG for a map titled "Sago Mine in Relation to Recorded Locations of Lightning Strikes, Gas Wells and Gas Lines" and Appendix EE for a report titled "Investigation of the Well Heads and Gas Pipeline System."

A measurement was taken to determine the earth resistance of Gas Well API# 47-097-01251, on the surface near the sealed area. A Lem Unilap NGI tester and the four-pole method were used. The test revealed the surface of the earth around the gas well had a resistance value of 2.49 ohms. Measurements between these points revealed a low resistance path. This indicates that lightning energy may readily dissipate in the earth near the well rather than travel into the mine.

#### *Conductors to the Sealed Area*

HydroGeophysics, Inc. conducted two other tests during the weeks of June 12 and July 17, 2006. The company conducted a geophysical survey to map the subsurface electrical properties of the region above the sealed area. This survey relied on induced fields to map all magnetic and electrical properties of this area and any metallic features such as well casings that might be present but unknown. The company also performed a surface to mine resistivity test, which mapped zones of gradient electrical resistance to establish the conductivity of the earth above the sealed area. These tests indicated that a direct, vertical low resistance metallic path or zone of reduced resistivity for lightning energy to travel from the surface to the sealed area did not exist. See Appendix FF an executive summary report titled "Geophysical Survey of the Old 2 Left Section of the Sago Mine."

### *Water in the Strata Over the Sealed Area*

Water samples were collected from surface streams, the right rib of the No. 8 entry on 2nd Left Mains and from the track entry between 32- 33 Crosscut, No. 3 Belt of the 2 North Mains below Trubie Run stream to assess the pH and electrical conductivity of water in the mine. This study was done to determine if electrical energy was capable of passing from the surface into the sealed area through water. The sample obtained from the No. 8 entry on 2nd Left Mains exhibited a high conductive property. A sample was not collected at or near the origination of the explosion because there was no water present. Based on the area of origination of the explosion in relation to the samples collected, it is highly unlikely that water entering the mine from the surface created a path for electrical energy to enter the sealed area and ignite an explosive mixture of methane gas. See Appendix HH, a report titled "Observation and Sampling Collection Methodology."

Based on observations and testing, Scenario B is unlikely. Sandia stated that it is unlikely that the vertical pipes would induce a significant amount of voltage onto the pump cable in the sealed area because the cable is perpendicular to the pipes.<sup>56</sup> Similar to the wire mesh, the gas lines and the well are grounded at regular intervals and would not support a large voltage potential. There was no evidence underground of the explosion originating in the entries nearest the gas well. Wicking of a methane layer from the area closest to the gas well is unlikely based on the distance, elevation, and uneven roof conditions from these entries to the origin of the explosion. HydroGeophysics, Inc. did not find a low resistance vertical path for lightning to travel into the mine. Also, conductive water was eliminated based on the origin of the explosion.

Scenario C - A lightning strike over the sealed area indirectly energizing metallic objects within the sealed area.

### *Indirect Energy Transfer To Sealed Area*

The current in a lightning strike has an associated magnetic field. Due to the relatively low frequency content of lightning (<100 kHz), electromagnetic energy can readily propagate through hundreds of feet of earth and induce a voltage onto an antenna or receiver. This process is referred to as indirect coupling. An electromagnetic field propagates through the earth as a result of a cloud to ground lightning strike or a long, low-altitude horizontal

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<sup>56</sup> A conductor that is perpendicular to another is severely limited in its ability to induce a voltage on the other, as compared with a conductor that is parallel to another.



current channel from a cloud to ground strike. Unlike direct coupling, indirect coupling does not require the presence of metallic conductors in a continuous path from the surface to areas inside the mine.

This scenario involves lightning occurring over the sealed area. There are several ways in which this could have occurred. The horizontal portion of a recorded lightning strike may have traveled over the sealed area. As discussed previously, both lightning detection systems have limitations and do not record all lightning strikes. An unrecorded strike may have occurred over the sealed area. This strike could have been a cloud to cloud, intra-cloud, cloud to ground or an upward discharge undetected by either system. A lightning strike in this area would induce a voltage on all nearby metallic objects, on the surface and underground.

Sandia conducted indirect drive tests. A test signal was generated on the surface over the sealed area where the explosion initiated and then was measured underground with instrumentation, a computer and an antenna. The objective was to identify the mechanism that would allow electromagnetic coupling of lightning energy into the sealed area of the mine. The soil and rock resistivities play a major role in determining the amplitude and frequency dependency of indirect coupling. The electric fields measured in the sealed area of the mine had amplitude and frequency characteristics which confirmed that they were caused by diffusion coupling from currents above the sealed area through the soil and rock overburden. The soil and rock resistivities used to model the coupling were comparable to those determined by HydroGeophysics, Inc.

The abandoned submersible pump in the 2nd Left Mains had a cable approximately 1,300 feet long which was found in four sections. It appeared to have been damaged by being pulled apart, rather than being severed. Mine management indicated that the cable was pulled into one or more sections as they tried to retrieve the pump prior to sealing the area. It could not be determined if some or all of the damage was caused by the explosion. Also, there was no evidence of arcing or sparking on any of these cable ends. See "Executive Summary of Submersible Pump Parts Recovered from Sago Mine" contained in Appendix II.

Approximately 196 feet of the pump cable abandoned in the sealed area was retrieved for testing by MSHA. The retrieved portion of the pump cable extended from cable break 1 to where the cable coupler was removed. That is the portion of cable nearest the origin of the explosion. The location of the cable is shown in Appendix Y-2, "Electrical Map, 2nd Left Mains, 2 North Mains Inby Crosscut 57." This portion of the cable had three permanent splices, one temporary splice and numerous damaged places in the outer jacket of the cable.

Testing of the three insulated power conductors (red, black, white), two ground conductors, and an insulated ground check conductor within the pump cable was performed. The test was conducted to determine if there had been a failure in the conductor's insulation and the cable's outer jacket. The ground wires in this cable are not provided with insulation.

The insulation on the power conductors is rated for 2,000 volts. The red conductor failed the test at about 700 volts. The black conductor failed when 1,600 volts was applied to it. The white conductor passed the test. Further testing on the white conductor was conducted to determine at what level failure would occur. It failed when 5,500 volts was applied. Each of the two ground conductors failed when 24 volts were applied to them. The ground check conductor passed the test with minimal leakage current. See Appendix JJ titled, "Sago Mine Pump Cable Test."

The Sandia test data revealed that during a lightning strike the insulated conductors of the abandoned pump cable could receive voltages as high as 20,500 volts. This voltage would be of a short duration but the energy generated would be adequate to cause an arc and ignite methane.

A cable with insulated conductors in an underground mine can act as an antenna or receiver. If a lightning strike occurs on the surface there could be a voltage induced onto the insulated conductors of the underground cable which may result in component failure. The component failure will be in the form of an insulation breakdown or arcing. If the conductors in the cable were frayed, they would be of such a small size that they could not carry the induced energy upon them by the lightning strike. The frayed portion of the conductors would act like fuses and burn apart causing an arc.



When a cable is connected to a coupler, the four insulated conductors are in close proximity to grounded conductors and the grounded shell of the coupler. A cable coupler contains exposed bare copper pins that connect to the red, white, black, ground and ground check conductor. Figure 43 is a photograph of the cable coupler.

**Figure 43 - Cable Coupler**



Figure 44 is a photograph of the end of the cable coupler containing the connecting pins and the conductors. These pins become energized to the same level as their connected conductors. The coupler was lying on the damp mine floor, the coupler pins were exposed to moist dirt that could provide a path to the grounded metal shell resulting in an arc.

**Figure 44 - Coupler with Pins and Conductors**



Damaged areas of a cable or its coupler are potential locations where arcs can occur. This cable had numerous damaged areas. Figure 45 is a photograph of two pieces of the cable. Therefore any cuts, nicks, pinholes, or other damage to the cable are potential points where an arc between the red, black, or white conductor and the grounding conductors could occur.

**Figure 45 - Two Pieces of the Cable**

Any of these arcs are potential ignition sources for the methane. Although there was no observed sign of arcing on the conductors, this does not rule out the possibility that an arc occurred, initiating the explosion.

The pump cable was not connected to a power source, and power sources were not located in the sealed area. No other equipment was found in the sealed area. Other metallic objects near the origin of the explosion include roof bolts, spider plates and wire mesh. These objects were not considered as plausible receivers or antennas of the electromagnetic energy that propagated underground because measurements indicated they were well grounded at regular intervals to the roof of the sealed area, and therefore would not support a large voltage potential.

Corona discharge can occur to any power conductor that is energized. When energized, it produces an electric field around the power conductor, unless the power conductor is shielded with a grounding shield. The strength of the electric field developed around the conductor is proportional to the conductor wire size, the shape of the conductor and the amount of voltage applied to the conductor. When the electric field strength reaches a specific value, the air molecules surrounding the conductor become ionized. Higher voltage levels produce a cloud of ionized gas surrounding the conductor. This process is called corona discharge and is a precursor to an arc. A corona discharge may ignite an

explosive gas mixture.<sup>57</sup> Sandia concluded it is unlikely that a corona discharge would develop before an electrical arc occurs due to the short duration of lightning.

Sandia's field measurements and analysis indicate that significant electromagnetic energy can be coupled into the sealed area of the mine. A lightning source, as stated above, would create an electromagnetic field similar to a magnetic field that is produced between the north and south poles of a magnet. The electromagnetic energy created by the lightning discharge would have then radiated through earth onto the pump cable, which could act as a receiver or antenna. The electromagnetic energy could induce a voltage onto the pump cable which generates an arc near the explosive methane mixture in the sealed area. Eyewitness accounts of simultaneous lightning and thunder above the sealed area at the time of the explosion lend further credence to this possibility. Measurements and analyses indicate that the pump cable is the most likely receiver of electromagnetic energy in the sealed area. This is the most likely ignition source for this explosion.

### **Origin**

The origin of an underground coal mine explosion is the location where the explosion begins. It is identified as the location from where primary explosion forces propagate in all directions. Primary explosion forces are the initial forces that occur at each location. In addition, the origin must be a location that includes a suspended accumulation of fuel, sufficient oxygen to support combustion of the fuel, and the ignition source.

In some cases, the ignition source can occur a short distance from the origin of an explosion. In these cases, the ignition source is located within an explosive concentration of layered fuel. Methane is a gas which normally forms layers in underground coal mines under certain conditions. The methane layer must be continuous, within its explosive range of 5% to 15%, and would generally be located near the roof. Upon ignition, the layer burns without the generation of forces and without generating turbulence in the mine atmosphere. This is commonly called "wicking." The burning layer eventually contacts a larger accumulation, resulting in an explosion. The explosion immediately generates primary forces propagating in all directions away from the origin.

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<sup>57</sup> Sacks, H. K., and Novak, Thomas, Corona Discharge Initiated Mine Explosion, IEEE Transactions on Industrial Applications, Vol. 41, Sept/Oct 2005.

Layering can occur in a mine atmosphere where the velocity of the airflow is not sufficient to generate turbulence in the airflow. The lack of turbulence prevents the mixing of gases throughout the mine opening. Sufficient ventilation can disperse a layer of mine gases.

On December 28, 2005, an examination was conducted at the 2 North Main seals and 0.2% methane was detected. The quantity of air measured in the split of air ventilating the seals was 4,392 cfm. The examiner detected 1.2% methane exiting the sample pipe in Seal No. 10. On December 30, 2005, the mine foreman visited the area and also found 0.2% methane in the split of air ventilating the seals. It is unlikely that wicking through the seal could occur due to the fully-mortared face on the active side of each seal. The gas sampling line in Seal No. 10 included a valve. The valve was reported to be closed and the line was not installed against the roof. The water trap in Seal No. 1 was reported to be full of water and was installed near the floor. There were no ignition sources near the seals. Although the burning of a layer leading to an explosion can be possible, no evidence was found to support wicking from outby the sealed area through the seals.

The distance through which a burning layer can pass is dependent on the conditions of the roof, such as undulations, and the ability of the layer of methane to remain within its explosive range. Within the sealed area, there were locations where accumulations of methane were possible. If the burning layer contacted any accumulation, an explosion would result. It is unlikely that a layer in the sealed area would have the ability to burn for more than a short distance.

Physical evidence was observed throughout the underground areas affected by the explosion. Physical evidence includes the deformation of structural materials, including belt hangers, roof support plates, and wire mesh. Also, the deposition of mine dust on mine surfaces and on equipment and roof bolts is considered to establish the direction of primary forces. This evidence was evaluated and was used to establish the point of origin, the extent of flame, and the direction of the primary explosion forces. Evidence indicated that the explosion was initiated within the sealed area near survey stations 4010 and 4011 in the 2nd Left Mains. Primary forces propagated away from this location in all directions, thus identifying this location as the origin of the explosion.

A typical underground coal mine explosion begins as methane is ignited. The ensuing fireball rapidly enlarges and eventually begins to propagate through the fuel. When propagation through the unburned fuel remains at a velocity below the speed of sound, the explosion is termed a deflagration. The forces developed during a deflagration are dependent on the speed of the flame. The faster the flame propagates, the higher the forces become. Deflagrations show limited, if any, pressure damage near the origin due to the fact that the flame is developing.

Figure 46 was taken near survey station 4010, facing outby in an area that had been second mined. All but two of the roof plates appear to be unaffected by the forces of the explosion, indicating that forces had not reached their peak magnitude.



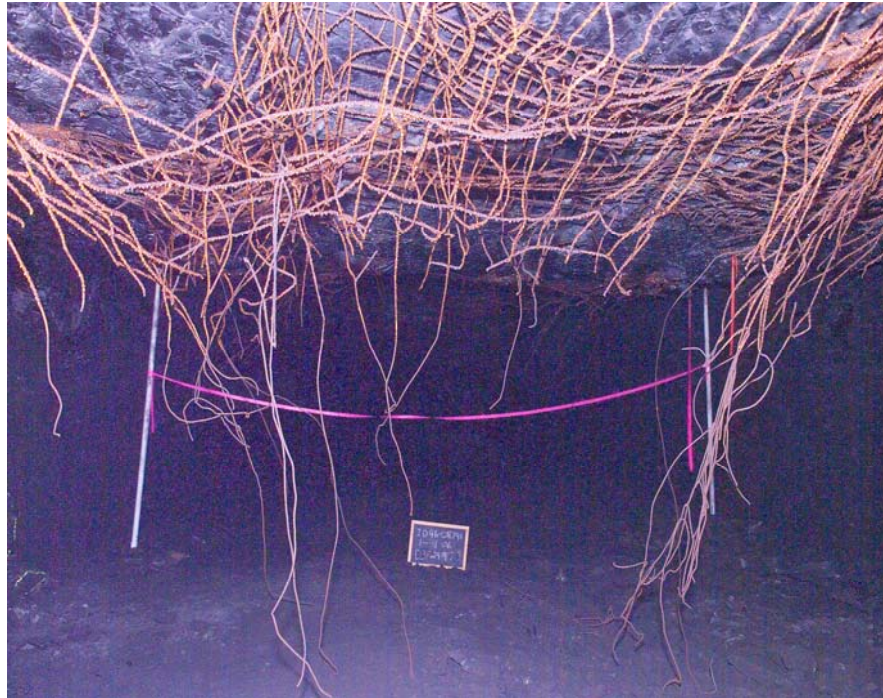
**Figure 46 - Picture taken Near Survey Station 4010**

The picture shown in Figure 47 was taken from a location near survey station 4011. There is no damage to roof support members, including wire mesh or roof plates. The origin of this deflagration-type explosion was located within the sealed area near survey stations 4010 and 4011 in the 2nd Left Mains. This particular location did not appear to be exposed to the same magnitude of pressures as the surrounding areas.



**Figure 47 - Picture Taken Near Survey Station 4011**

Figure 48 was taken near Seal No. 8. It shows extensive damage to the wire mesh. Pressures from a deflagration increase as the flame travels away from the origin in all directions. Higher pressures are achieved as the flame speed continues to increase.



**Figure 48 - Picture Taken Near Seal No. 8**

Bottom mining was not conducted in the areas where the seals were constructed. Therefore, as the flame approached the location of the seals, the size of the entries decreased. These restrictions caused the mine atmosphere to become pressurized prior to the arrival of the flame front. When the flame entered the pressurized mine atmosphere, the pressures increase. This is commonly known as pressure piling.

Pressures associated with a deflagration followed by pressure piling are different from pressures associated with detonations of fuel. Deflagrations begin with low pressures and low flame speeds. When restrictions are encountered during a deflagration, pressure piling effects can result in excessive pressures. Pressure piling during a deflagration can result in a deflagration to detonation transition (DDT).

A detonation occurs when the reaction moves through the unburned fuel at a speed that exceeds the speed of sound. Explosions that begin as detonations result in excessive pressures at the origin of an explosion. The same direction of

pressure can occur as in a deflagration but variations in the magnitude can be used to identify the type of explosion and the origin.

A methane accumulation was ignited within the sealed area near survey stations 4010 and 4011 in the 2nd Left Mains. A deflagration began as the flame propagated in all directions from the origin. During the outby propagation of the explosion, flame speeds and pressures increased. As the flame approached the location of the ten Omega block seals, it propagated through an area with a pressurized mine atmosphere caused by the presence of the seals. In addition, the mine openings became restricted as the flame passed out of the area that had been bottom mined. The pressurized mine atmosphere, along with the increased pressure due to height restrictions, caused pressure piling to occur. This condition resulted in excessive pressures which completely destroyed the ten seals. Appendix LL contains a mine map that details the extent of flame and the direction of the primary explosion forces.

## **Flame**

### **Extent of Flame**

A Mine Dust Survey was conducted throughout underground areas after the explosion. The mine dust samples were sent to MSHA's Laboratory in Mount Hope, West Virginia for analysis. Each of the mine dust samples was subjected to an Alcohol Coke Test. The Alcohol Coke Test identified the portion of coke in each of these samples. Coke occurs as coal is de-volatilized during a heating process, allowing mainly carbon to remain. The results of the Alcohol Coke Test indicated the quantity of coke in each sample as either none, trace, small, large, or extra large. Large and extra large quantities of coke in the post-explosion mine dusts are indicative of underground areas exposed to explosion flame. However, it is possible for mine dust samples within the flame zone to show none, trace, or small quantities of coke. For example, the explosion flame can travel at a velocity that is too fast to allow sufficient time for coal to coke or if coal dust is not dispersed into the explosion flame.

In the 2nd Left Mains, located entirely within the sealed area, coke indicating flame was found in every sample. In the 2 North Main entries inby the location of the ten seals, coke indicating flame was found in most samples. The flame from the explosion did propagate throughout an extensive area of the 2nd Left Main entries and the inby portions of the 2 North Main entries. However, due to the large number of mine dust samples that could not be collected in these entries, it was not possible to accurately determine the location of the inby edge of the flame.



In the 2 North Main entries outby the location of the ten seals, coke indicating flame was only found in two samples. The flame from the explosion did not propagate significantly outby the location of any of the ten seals, with the exception that flame extended for a short distance outby the seal locations in the Nos. 7 and 8 entries.

In both 1st Left and 2nd Left Parallel, coke indicating flame was not found in any samples. The flame from the explosion did not propagate into either 1st Left or 2nd Left Parallel.

The flame of an explosion is extinguished due to a lack of fuel, suspension, heat, oxygen, confinement, or a combination of these five factors. The extent of flame is shown on the mine map in Appendix LL.

### **Fuel and Suspension**

Methane is naturally suspended as it enters the mine workings. Prior to the explosion, coal dust would not have been suspended in the mine atmosphere on either side of the ten seals. When the minimum explosive concentration of coal dust is suspended, the cloud is so dense that you cannot see through it nor can you breathe in it. Research has shown that ignition of as little as 13 cubic feet of methane, diluted to within the explosive range, would be sufficient to suspend and ignite a coal dust cloud.<sup>58</sup> Coal dust may have been involved to a limited degree throughout the sealed area as the flame propagated.

Methane provided the primary fuel for the explosion. After ignition, the explosion propagated away from the origin in all directions. Explosive quantities of methane, in the range of 5% to 15%, were initially available for the explosion. It is possible that these explosive accumulations existed throughout the entire cross-sectional area of some entries and crosscuts. Concentrations in excess of the explosive range of methane were probably present in the sealed area prior to the explosion. A portion of these methane layers may have been diluted into the explosive range due to the turbulence of the propagating explosion. As the methane explosion propagated, a shock wave occurred with its resultant overpressure. This overpressure may have resulted in the suspension of mine dust, including coal dust, from the mine roof, ribs, and floor. Methane remained suspended for the duration of the explosion. The flame was not extinguished due to a lack of fuel or a lack of suspension.

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<sup>58</sup> The Explosion Hazard in Mining, U.S. Department of Labor, Mine Safety and Health Administration, Informational Report 1119 (1981), John Nagy, Page 56.

## Heat

Explosion flames exceed the ignition temperatures of both methane and coal dust. Rock dust and other incombustible dusts in suspension reduce the heat available for continued flame propagation. When an area is wet, coal dust will not become readily suspended during an explosion and therefore will not become involved in its propagation. Rock dust or other incombustible dusts in sufficient suspended quantities can extinguish or prevent a coal dust explosion.

In addition to the available rock dust, Omega blocks are manufactured of incombustible material. A significant quantity of Omega blocks were used to construct the ten seals. Broken and unused Omega blocks were sometimes placed along rutted entries and crushed by the operation of mining equipment. This deliberate action filled ruts and unintentionally provided additional incombustible material in the area. In addition, the force of the explosion, coupled with a high degree of impact damage from collision with ribs and wood crib blocks, resulted in the pulverization of a significant portion of many Omega blocks and the suspension of the resulting dust. Figure 49 shows debris along the rib outby Seal No. 2. This debris included a significant amount of pulverized Omega blocks.



**Figure 49 - Picture of Debris Outby Seal No. 2**

Research has shown that explosion flame cannot successfully penetrate ten feet into a cloud of coal dust suspended at a concentration of 5.0 ounces per cubic

feet.<sup>59</sup> This shows that dense dust clouds, regardless of their composition, will not allow the propagation of explosion flame to penetrate. Such a sufficiently dense cloud of suspended dust may have existed at the location of the ten seals as the explosion flame approached. This suspended dust may have acted as a heat sink, which prevented the continued propagation of the explosion flame into the active workings. Therefore, the loss of sufficient heat may have been a factor responsible for extinguishing the explosion flame at the location of the ten seals.

## Oxygen

Methane requires at least 12% oxygen to become or to remain involved in any combustion process.<sup>60</sup> Where flame evidence existed throughout the sealed area, it is certain that oxygen concentrations above this minimum occurred. The active workings would have contained an oxygen concentration of about 20.9% before and during the explosion. The flame of the explosion consumed most of the oxygen. The flame of an explosion would generally not be able to burn back through the same area because of the lack of oxygen immediately after the explosion. Oxygen concentrations after a methane explosion could be less than 4%, depending on the initial methane concentration.<sup>61</sup> The explosion flame propagated outward in all directions from the point of origin near survey stations 4010 and 4011 in the 2nd Left Mains. The lack of oxygen prevented the flame from burning through the same area twice but did not extinguish the propagating flame front traveling in all directions.

## Confinement

Confinement is related to the cross-sectional area of the opening where a propagating explosion travels. It allows pressures to continue and, if the explosion is fueled by dust, it keeps the fuel particles in close proximity to one another. If the opening size increases or if additional entries become available for the flame front, confinement could be lost. The loss of confinement would cause a decrease in the speed of the explosion and a resulting reduction in pressure. The lack of confinement did not occur and was not responsible for extinguishing the explosion flame.

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<sup>59</sup> Id, page 36.

<sup>60</sup> Limits of Flammability of Gases and Vapors, U.S. Bureau of Mines, Bulletin 503, (1952), Page 131.

<sup>61</sup> The Explosion Hazard in Mining, U.S. Department of Labor, Mine Safety and Health Administration, Informational Report 1119, (1981), John Nagy, Page 63.

## Sealed Areas

Past explosion research was concentrated in unrestricted entries. Prior to 2006, neither the USBM nor NIOSH conducted full-scale explosions in sealed areas. No specific mining publications were available detailing the effects of the flames and forces of a propagating explosion in a sealed area. Also, MSHA has not traveled into the sealed area during the investigation of any previous explosions which occurred in sealed areas. Little research has been conducted to quantify the effects of pressure piling in coal mines.

### Force

An explosion can propagate as a deflagration or a detonation. A deflagration occurs when the reaction moves through the unburned fuel at a speed that remains below the speed of sound, which is about 1,129 feet per second (fps) at 70°F. A detonation occurs when the reaction moves through the unburned fuel at a speed that exceeds the speed of sound. In the underground coal mine environment, deflagrations are typical. Both deflagrations and detonations can produce excessive pressures. A factor which can significantly increase the pressures at any particular location is known as pressure piling. Pressure piling occurs when the mine atmosphere becomes pressurized prior to the arrival of the flame front. One physical factor that can lead to pressure piling occurs when the total dimensions of the opening through which the explosion is propagating become increasingly restricted, thus the flow of gases for pressure equalization is inhibited.

### Deflagration

After ignition of methane, the flame of a deflagration heats the mine atmosphere. The heated atmosphere expands as a result. This expansion exerts a pressure on mine surfaces, equipment, ventilation controls, and miners. This pressure is sometimes referred to as a shock wave. The faster the flame propagates, the higher the pressures become. Regardless of the speed of the flame, it can not overtake the shock wave. Research has indicated that flame speeds of approximately 400 feet per second (fps) may result in pressures of about 7 psi. When the flame increases in speed to near 1,000 fps, research indicates that the expected force may be on the order of 17 psi.<sup>62</sup> Many conditions underground can affect the magnitude of explosion pressure including, but not limited to; change in height or width of opening, the presence of large equipment, change in the number of entries or crosscuts, the concentration of fuel being consumed, the

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<sup>62</sup> Id, page 62.

strength of the ignition source, the percentage of suspended dust that is incombustible, and the amount of oxygen available for combustion.

The calculated theoretical value of maximum static pressure for coal dust or methane explosions in closed vessels is about 140 psi.<sup>63</sup> The maximum pressure that can be expected from an explosion fueled by either coal dust or methane traveling at deflagration speeds in an underground coal mine would be less than 100 psi.<sup>64</sup> In an underground explosion, complete combustion does not occur and heat is lost to the mine surfaces, which accounts for the lower pressure. As the speed of the flame decreases and the flame eventually terminates, pressures reduce and are eliminated. According to the U. S. Bureau of Mines (USBM) Report of Investigations (RI) 7581 entitled "Explosion-Proof Bulkheads," with adequate incombustible material and minimum coal dust accumulations, it is doubtful that pressures exceeding 20 psi could occur very far from the origin of the explosion. Several oscillations of pressure can occur before ambient conditions are reached. This allows for pressure in both directions to occur at each underground location within the explosion zone. The mine map shown in Appendix LL shows the direction of the primary forces. The primary force is the first, or initial, force at each location shown.

### **Pressure Piling**

The explosion pressures achieved during pressure piling are contingent upon the compression of the fuel ahead of the flame. This compression of the fuel increases as the speed of the flame increases and as the opening becomes more restricted. The explosion pressure in a pre-compressed fuel/air mixture is proportional to the absolute pressure. If the mine atmosphere is pre-compressed to about 45 psi, the instantaneous explosion pressure could be as high as 300 psi. As an example of pressure piling, computations after one coal dust explosion experiment in a dead end entry indicated that a peak static pressure of not less than 595 psi was reached.<sup>65</sup>

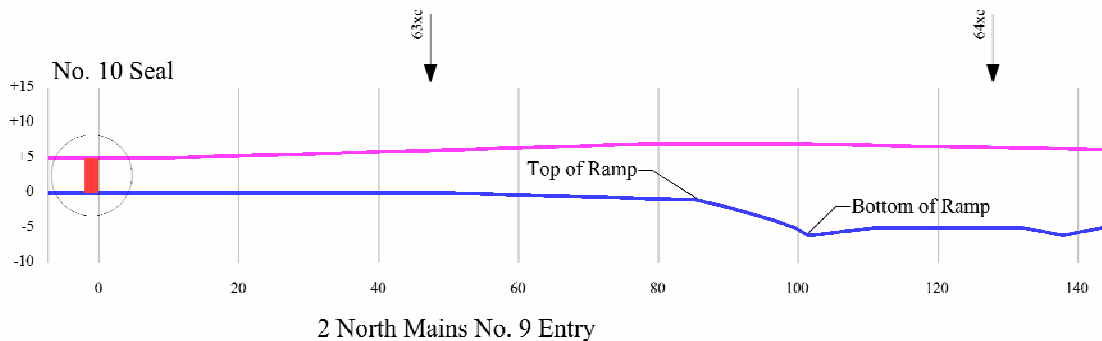
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63 Id, page 69.

64 Id, Page 58.

65 Coal Dust Explosions and Their Suppression, National Center for Scientific, Technical and Economic Information, Warsaw, Poland, (1975), p. 284.

Figure 50 shows a typical side view of the entry in which Seal No. 10 was constructed. The seal is shown on the left. The line across the top of the figure shows the elevation of the roof. The line across the bottom of the figure details changes in the mine floor due to bottom mining. Those areas to the right of the seal location shown in the figure are part of the sealed area. The height of the entry at the bottom of the ramp, where bottom mining commenced, is approximately 2.5 times the height at the location of the seal.



**Figure 50 - Contours Near Seal No. 10 in 2 North Mains, No. 9 Entry**

As the explosion propagated toward the location of the ten seals, the mine atmosphere immediately behind the seals would have experienced increased pressure due to the shock wave of the approaching flame front. Pressures would have increased dramatically as the explosion propagated up the ramp into more restricted entry heights. The pressurized mine atmosphere immediately behind the seals would have caused pressure piling effects.

## Detonation

In a detonation, shock waves may develop at the flame front. These shock waves advance ahead of the flame and reinforce each other in the unburned fuel/air mixture. When the energy in these shock waves is sufficient, self-ignition of the mixture occurs and new, multiple flame fronts develop. The instantaneous static pressure from the detonation may be several times higher than 100 psi. The static pressure in a mine explosion can be as little as a fraction of a pound per square inch or more than 600 psi.<sup>66</sup>

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<sup>66</sup> The Explosion Hazard in Mining, U.S. Department of Labor, Mine Safety and Health Administration, Informational Report 1119, (1981), John Nagy, Page 60.

## NIOSH Assistance

NIOSH, at MSHA's request, initiated two test explosions in the face area of Drift C of Lake Lynn to compare the effects of an explosion in a sealed area and an explosion in an open entry. The same amount and concentration of methane and the same ignition source were used for both explosions. In the first explosion, labeled as #501, seals were constructed in the first three crosscuts between Drift C and Drift B at distances of 59 feet, 156 feet, and 256 feet from the face. Drift C remained open. Also, two cribs were constructed in the entry about 312 feet from the face. In the second explosion, labeled as #502, the seals in the crosscuts remained in place. A fourth seal was constructed across Drift C at a distance of about 320 feet from the face, effectively sealing the inby area of Drift C.

The seal in No. 1 Crosscut was the same for both tests and was constructed of solid concrete blocks, according to 30 CFR 75.335. The seal in No. 2 Crosscut was the same for both tests and was an Omega block seal constructed in the same manner as the Omega block seal that passed explosion testing in 2001. The seal in No. 3 Crosscut was the same for both tests and was the hybrid Omega block seal. This seal was built with the following conditions: applying dry mortar on the mine floor, not applying mortar directly to the vertical joints of the first course of blocks, and modifying the installation of wood planks and wedges between the last course of the Omega blocks and the mine roof. For test #502, an Omega seal constructed in the same manner as the Omega block seal that passed explosion testing in 2001 was built across Drift C. Pressure readings were recorded at locations where transducers were mounted in panels along Drift C. Table 11 contains the results for both explosion tests #501 and #502.

**Table 11 - Results of Explosion Test #501 and #502 at Lake Lynn**

Location	Distance from Face (feet)	Test #501 Pressure (psi)	Test #502 Pressure (psi)
No. 2 Crosscut	156	22	22
No. 3 Crosscut	256	25	38
Crib	312	28	--
Test Seal	320	--	50
Outby	403	14	5
Outby	501	9	4
Outby	598	6	3.5
Outby	757	4	3

The results shown above indicate that seals do affect the magnitude of the pressure achieved at locations both inby and outby the seals. The test seal in Drift C was about 320 feet from the face. In Test #501, the maximum pressure achieved was 30 psi and occurred at the face. The pressure on the seal in No. 2

Crosscut was 22 psi and on the seal in No. 3 Crosscut was 25 psi. This slight increase in pressure was possibly attributed to the distance it took to involve the suspended coal dust. Subsequently, this pressure began to deteriorate as it traveled outby, however the two cribs constructed in the entry caused the pressure to increase to 28 psi. This increase was recorded at a distance of 312 feet from the face. Within 53 feet, the pressure had dropped to 14 psi and after traveling another 195 feet, which corresponds to the location approximately 598 feet from the face, the pressure had dropped to 6 psi. At 757 feet from the face, the pressure had dropped to 4 psi.

In Test #502, the seal in No. 2 Crosscut was 156 feet from the face and the maximum pressure on this seal was 22 psi. The seal in No. 3 Crosscut was 256 feet from the face and the maximum pressure on this seal was 38 psi. This significant increase in pressure can most likely be attributed to pressures rebounding or reflecting after impacting the seal in Drift C, prior to its destruction. The maximum pressure increased to 50 psi at the location of the seal in Drift C, which was 320 feet from the face. When the pressure wave reached 403 feet from the face, the pressure had dropped to only 5 psi. This drop is very significant in that pressures decreased 90%, from 50 psi to 5 psi, in a distance of only 80 feet. The flame of the explosion had most likely consumed all the available fuel and propagation of the explosion was not continuing. However, the pressures that developed impacted the seal across Drift C and rebounded toward the face. The primary thrust of the pressure wave did not head outby after rebounding. At 757 feet from the face, the pressure had dropped to 3 psi.

### **The Sago Mine Explosion**

A methane explosion initially occurred in 2nd Left Mains in the general area of survey stations 4010 in the No. 6 entry and 4011 in the No. 7 entry. These survey stations are located in the No. 2 Crosscut. As the flame from this explosion expanded, it began to propagate through explosive concentrations of methane in all directions. Some of the sealed area may have included no methane or methane at concentrations below 5%. Additionally, concentrations of methane above the explosive limit were probably present in some locations throughout the sealed area prior to the explosion. A portion of this methane may have been diluted into the explosive range due to the turbulence of the propagating explosion. Methane that remained in concentrations outside the explosive range did not become involved in the explosion. It appeared that the flame and the associated forces initially traveled inby and outby through the Nos. 6 and 7 entries. The length of flame and the generation of forces in any direction are dependent on the amount of explosive methane accumulations in that direction. It is typical in underground coal mine explosions that limited forces occur at the origin of the explosion.



The explosion propagated inby in the Nos. 6 and 7 entries of 2nd Left Mains. The flame and forces traveled in both directions from these entries through each crosscut. Subsequently, the flame and forces involved each entry of 2nd Left Mains and continued propagating inby. Although the inby extent of the flame is unknown due to the lack of mine dust samples, the forces would have affected all of 2nd Left Mains to varying degrees. The most inby mine dust sample was taken in the No. 5 Crosscut. The magnitude of the forces would have varied greatly, especially as the explosion was directly affected by change in cross-sectional dimensions of the entries and crosscuts. The mine map in Appendix H-4, "2 Left Mains" shows the extent of bottom mining throughout the 2nd Left Mains. As the flame and forces traveled through the crosscuts toward the No. 1 entry, stoppings were destroyed. Stoppings and overcasts can be destroyed by explosion forces of between 2 and 4 psi. Ventilation controls were damaged throughout the area affected by the explosion. This and other damage throughout the 2nd Left Mains is indicated on the mine map in Appendices H-1 through H-9.

The explosion propagated outby in the Nos. 6 and 7 entries of 2nd Left Mains. The explosion flame and forces entered the 2 North Mains throughout Nos. 65 and 66 crosscut. The flame and forces headed in both directions through each entry in 2 North Mains. Subsequently, the flame and forces involved each entry of 2 North Mains and continued propagating both inby and outby. Although the inby extent of the flame is unknown due to the lack of mine dust samples, the forces would have affected all of 2 North Mains inby the seals to varying degrees. The most inby mine dust sample was taken in the No. 3 entry, just inby No. 66 crosscut. The magnitude of the forces would have varied greatly, especially as the explosion was directly affected by change in cross-sectional dimensions of the entries and crosscuts. The mine map in Appendix H-4, "2 Left Mains" shows the extent of bottom mining throughout the 2 North Mains.

Bottom mining occurred inby the location of the seals in the entries but not in the crosscuts of 2 North Mains. Bottom mining occurred as close as about 60 feet inby the location of the seals. Entry heights increased from about 6 feet at the location of the seals to about 20 feet at some locations in the areas that had been bottom mined. As the explosion propagated outby in the entries of 2 North Mains, the total height of the opening through which the explosion was propagating became increasingly restricted as the explosion approached the seals. This restriction resulted in pressure piling, as explained earlier. A resulting and drastic increase in the explosion pressures occurred at the location of the restriction and at each of the seals. The increase in pressures was not on the order of magnitude necessary to cause a deflagration to detonation transition (DDT).

Visual observations were made of the remnants of the ten seals at the Sago Mine. Visual observations were also made of the post-explosion condition of each of the seals constructed at NIOSH's Lake Lynn Experimental Mine. Conditions at these two mines are not identical, but comparisons were made concerning the destruction of the Omega blocks at different pressures. The damage to the seals at the Sago Mine was more extensive. This comparison would indicate that the pressures exceeded 93 psi at the location of the seals at the Sago Mine.

One victim who suffered fatal injuries was found about 556 feet outby the seal in the No. 6 entry of 2 North Mains. The exact location of this miner at the time of the explosion could not be established. His death was attributed to carbon monoxide intoxication. No traumatic physiological injuries were present, indicating pressures of less than 5 psi at his location.

The 2nd Left Parallel crew survived the flame and forces of the explosion without experiencing any known traumatic physiological injuries. McCloy indicated that he felt wind and heard noise. He felt pressure in his ears but they did not pop. Although the miners may have been on the section, the exact location at the time of the explosion could not be established. A significant reduction in explosion pressures occurred in 2 North Mains just outby the seals. These reduced pressures would have propagated into the crosscuts of 2 North Mains and traveled hundreds of feet before having any impact on the 2nd Left Parallel crew. This indicates they may have been affected by a pressure wave of less than 2 psi.

The 1st Left crew was located in a mantrip at the 1st Left switch when the explosion occurred. They were in direct line with the seals and the explosion forces. They were impacted by flying debris and a rush of air, which reportedly lasted for about 8 seconds. The mantrip operator was knocked down by the force of the explosion. They did not hear any noise. They did not smell any smoke initially. They did not see any flash or flame. After the rush of air, the atmosphere was very dusty. They did not experience any traumatic injuries resulting in physiological damage such as lung damage from pressure, ruptured ear drums or broken bones. Tests of the mine dust, as well as their testimony, indicated the flame from the explosion did not extend to their location. This indicates they may have been affected by a pressure wave of about 2 psi.

## ROOT CAUSE ANALYSIS

A root cause analysis was conducted. Root causes were identified that could have mitigated the severity of the accident or prevented the loss of life. Listed below are root causes identified during the analysis and their corresponding corrective actions to prevent a recurrence of the accident.

Root Cause:

The 2 North Main seals were not capable of withstanding the forces generated by the explosion.

Corrective Action:

Seals should be designed and installed to prevent an explosion from propagating to the opposite side.

Root Cause:

The atmosphere within the sealed area was not monitored and it contained explosive methane/air mixtures.

Corrective Action:

The atmosphere in existing sealed areas should be monitored and maintained inert when the seals are not capable of withstanding the forces of an explosion.

Root Cause:

Lightning was the most likely ignition source for this explosion with the energy transferring onto an abandoned pump cable in the sealed area and providing an ignition source for the explosion.

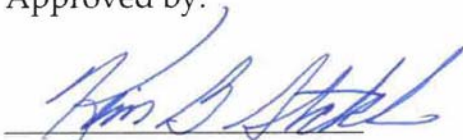
Corrective Action:

Insulated cables and conductors should be removed from the area to be sealed prior to seal completion.

## CONCLUSION

On January 2, 2006, an explosion occurred at approximately 6:26 a.m. in the mined-out area known as 2 North Mains and 2nd Left Mains of the Sago Mine. Lightning was the most likely ignition source for this explosion with the energy transferring onto an abandoned pump cable in the sealed area and igniting the methane that had accumulated within the sealed area. The ensuing explosion generated forces in excess of 93 psi and destroyed the seals, filling portions of the mine with toxic levels of carbon monoxide. One miner died of carbon monoxide poisoning shortly after the explosion. The 2nd Left Parallel miners' attempt to evacuate was unsuccessful and they barricaded themselves on the 2nd Left Parallel section. Unfortunately, the barricade was not able to prevent high levels of carbon monoxide from reaching the miners before they could be rescued. As a result, 11 additional miners perished and one survived.

Approved by:



Kevin G. Stricklin  
Acting Administrator for  
Coal Mine Safety and Health

## ENFORCEMENT ACTIONS

A 103 (k) order was issued to Wolf Run Mining Company, Sago Mine, on the morning of the accident to insure the safety of all persons at the mine. The order was modified numerous times to allow for the rescue and recovery operations, and then the accident investigation, to proceed. This order remained in place for the extent of the investigation.

A contributory citation is one issued for a condition that leads to the causes and effects or the severity of the accident. No contributory citations were issued to the mine operator as a result of the accident investigation. As indicated in the report, safety standard violations were identified with respect to seal construction, SCSR training, emergency notification to MSHA and mine rescue teams, lightning arresters and various other violations. In addition to the 103 (k) order, 149 non-contributory citations/orders were issued as a result of this investigation. One hundred seventeen were issued previously and 32 have been issued with the release of this report. Some of the more significant enforcement actions are addressed below along with an explanation of why they were not deemed contributory.

- Although the 2 North Main seals were not built in accordance with the approved ventilation plan requirements, the forces generated by the explosion would have completely destroyed the seals even if they had been built in compliance with the plan.
- Several miners did not don their SCSRs immediately after the explosion as required and some apparently removed the units to communicate or to perform physical work. However, those who did not don their SCSRs successfully evacuated the mine. The miners on the 2nd Left Parallel section donned their SCSRs but were exposed to high levels of CO far beyond the one-hour time capacity for each SCSR.
- MSHA and mine rescue teams were not immediately notified of the accident. This is an important requirement in order to maximize professional assistance. However, had agency officials and the mine rescue teams arrived earlier, the teams would not have been permitted underground any earlier than actually occurred due to the high levels of toxic gases and the possibility of another explosion. Even if the mine rescue teams had been on site and entered the mine immediately after the accident, they would have been withdrawn when they encountered the high carbon monoxide levels.

- Five electrical circuits entering/exiting the mine did not have lightning arresters. Testing indicated that a direct lightning strike onto these circuits could not have traveled far enough into the mine to initiate the explosion.

Even though these violations did not directly lead to the cause and effect or the severity of the accident, they are important matters that miners and the mining industry should be aware of and attentive to in order to prevent and minimize coal mine accidents.