REPORT of INVESTIGATION

into the

SAGO MINE EXPLOSION

which occurred JANUARY 2, 2006

UPSHUR CO. WEST VIRGINIA

WEST VIRGINIA OFFICE of MINERS' HEALTH, SAFETY, AND TRAINING

DECEMBER 11, 2006

RON WOOTEN, DIRECTOR

State of West Virginia
Joe Manchin III, Governor

WV Office of Miners' Health, Safety & Training
Ronald L. Wooten, Director
1615 Washington Street East • Charleston, West Virginia • 25311-2126
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The West Virginia Board of Coal Mine Health and Safety
1615 Washington Street, East
Charleston, WV 25311

Gentlemen:

There follows the report of the West Virginia Office of Miners' Health, Safety and Training, regarding the fatal explosion at the Sago Mine, which occurred on January 2, 2006. This represents the final report of the Agency on this matter.

You may note as you read the report that all questions may not be answered. The Investigative Team recognizes this and continues to seek those answers. We recognize, however; answers to all questions associated with this tragedy may never be answered. Because of this uncertainty, it is important to move forward with our report. As the Team continues its work, should additional answers be found, the report will be supplemented. Additionally, it is important that we focus our efforts on doing what we can to assure that nothing similar occurs in the future. This will be the primary goal of our investigators as they move forward.

The Investigative Team will be available to answer any questions that you may have. Once you have read the report, please notify this agency and we will reassemble the Team in an effort to completely respond to your questions.

Respectfully Submitted,

Ronald L. Wooten
Director

• **Region One** • 205 Marion Square - Fairmont West Virginia 26554-2800 • Telephone 304-367-2706 • Fax 304-367-2707
• **Region Two** • 891 Stewart Street - Welch, West Virginia 24801-2311 • Telephone 304-436-8421 • Fax 304-436-2100
• **Region Three** • 137 Peach Court - Suite 2, Danville, West Virginia 25053• Telephone 304-369-7823 •Fax 304-369-7826
• **Region Four** • 142 Industrial Drive- Oak Hill, West Virginia 25901-9714 • Telephone 304-469-8100 • Fax 304-469-4059

CONTENTS

DEFINITIONS

WV Office of Miners' Health Safety and Training: Various abbreviations used in this report include WVOMHS&T, WVMHS&T of OMHS&T

NIOSH: National Institute for Occupational Safety and Health

Portal: Mine entrance (a.k.a. "drift" or "drift mouth")

Mains: Major travel-way of a mine. Starting at the portal and usually continuing to the farthest extend of the mine.

Section: Work area of a mine. The location where coal is actively extracted for the mine.

Face: Farthest extent of the mining section. Area where the coal is actually extracted.

Mouth: Beginning of the section. Area where section branches from the mains.

Inby: Direction or location from your present location and progressing in an inward direction of the mine (looking / moving from the outside - in).

Outby: Direction or location from your present location and progressing in an outward direction of the mine (looking / moving from the inside – out).

First mining: The initial development of a section. Mining in an area where the mine has not been developed. (a.k.a. "advance mining").

Second mining: Additional mining of support pillars or sometimes a lower coal seam that commences, after first mining is completed, as the sections withdraws outby (a.k.a. "bottom mining" or "retreat mining).

Bottom mining: A special form of retreat-mining where a lower coal seam is recovered.

Omega blocks: A relatively lightweight cementaceous block used in the construction of seals, stoppings, and overcasts.

Seal: A barrier / wall constructed across all the entries of an abandoned area. This barrier / wall isolates the abandoned portion of the mine from the active portion of the mine.

Stopping: A wall constructed in the crosscuts between adjacent entries in series to channel fresh air to working areas (intake air) and channel contaminated air away from the working area (return air).

Overcast: A structure that channels two separate air courses through an intersection. (similar to a road intersection crossing.)

Omega block seal: A seal constructed of Omega blocks and high strength mortar. Has a minimum construction criteria to protect the active area from abandoned areas.

Omega seal: The term is used mostly in this report to that specific line of Omega block seals built across the mouth of Old 2nd Left Section.

ERRATA

Corrections made to report text subsequent to January 25, 2007 posting to www.wvminesafety.org

Bold: text which has been added

~~strike-through~~: text which has been deleted

Section 5.2-1

p. 2, line 12: The elevation control points provided have been compiled into a set of contour maps by OMHS&T and are included in Appendix ~~5.4~~ **5.4-1**: Floor Contour Map/ Roof Contour Map.

Section 5.5-1

p. 4, line 2: Deficiencies were found, both on the surface and underground, resulting in 33 non-contributing violations being issued by the West Virginia Office of Miners' Health, Safety & Training. (Appendix ~~5.5-1~~ **5.1**: Statistics and Fact Finding).

p. 5, line 1: On January 5, 2006, the OMHS&T ordered a report of lightning strikes in the Sago area at about the time of the explosion from Vaisala-Thunderstorm[1] in Tucson, Arizona Vaisala provided strike locations in latitude and longitude coordinates, together with estimates of the peak current in the discharges and the polarity (see Appendix ~~5.1-1~~ **5.5-2**: STRIKEnet Report LA105304).

Section 5.5-2

p. 6, footnote (5): [5] Memorandum to Doug Conaway from Monte Hieb dated January 12, 2006 (see Appendix ~~5.5~~ **5.5-2**)

1 EXECUTIVE SUMMARY

This report by the West Virginia Office of Miner's Health, Safety and Training presents a summary of findings into the Sago Mine explosion approximately 11 months after the date of its occurrence the morning of January 2, 2006. In that explosion, 12 men lost their lives. Fourteen (14) men walked to safety and another was rescued and carried to safety.

Beginning with an account of the events of that day, much of it through the eyes and words of the men who lived through it, this report will document the chain of events of the mine emergency and the mine rescue. This is followed by information and references pertaining to the mine recovery and the events leading up to the point at which the investigation underground could get underway.

The cause of the explosion has been determined to be a methane explosion that occurred at 6:26 AM and 35 seconds behind the seals of the Old 2nd Left Section (sometimes referred to as Old 2nd Left Mains or even 3rd Left). Ten (10) mine seals built of Omega blocks to seal off this part of the mine from the active mine were completed exactly one year prior to the date of this report (December 11). It was 22 days after December 11, 2005 that an explosion involving up to 400,000 cubic feet of methane gas destroyed these seals. The effects of this blast—the dust, the smoke, the debris across the entries—resulted in entrapment of the men of Two Left Section, who perished there, with the exception of Randal McCloy. Also partly at fault were self-contained self rescuers that did not perform in the manner expected.

A discussion of the SCSR's, is presented in Section 5.6.

That the seals sustained high explosive forces from the mine explosion is undeniable. Why the pressures were so high is becoming clear, but is not yet proven. At this writing the evidence supports a conclusion that the force of the explosion was far in excess of the 20 psi static pressure that was the criteria for their design, approval, and construction. These facts are corroborated by the preliminary results of a series of six (6) seal explosion tests performed at the Lake Lynn Experimental Mine between April 15, 2006 and October 19, 2006.

The cause of the explosion is clearly related to lighting. This conclusion is presented by strong corroborated circumstantial evidence presented in Section 5.5-2.

How the electricity from lightning entered the sealed area is still under investigation, and in that regard this report is not complete. Testing designed to determine if electricity can travel through the belt structure or track, transmitted by induction though the solid earth were recently performed by Sandia National Laboratories under the direction of the Mine Safety, and Health Administration (MSHA). The results of these tests are not yet released.

This agency proposes to continue its examination of lightning transients during the winter of 2006 – 2007 at Sago through the monitoring of transient voltages and currents of electricity with simple electricity-sensing devices that can be stationed at strategic locations in the mine to monitor for any lightning effects.

The phenomena of upward lightning or triggered lighting as a potential mechanism for the introduction of lightning electricity into the sealed area is currently being examined by this agency, and is discussed in Section 5.5-3. It is a phenomena tied to strikes of positive polarity which are much more common during electrical storms in the winter and involves lightning striking the ground at one location and returning to the sky as an upward stroke at an elevated structure as much as several miles away.

2 FOREWORD

2.1 Description of Mine

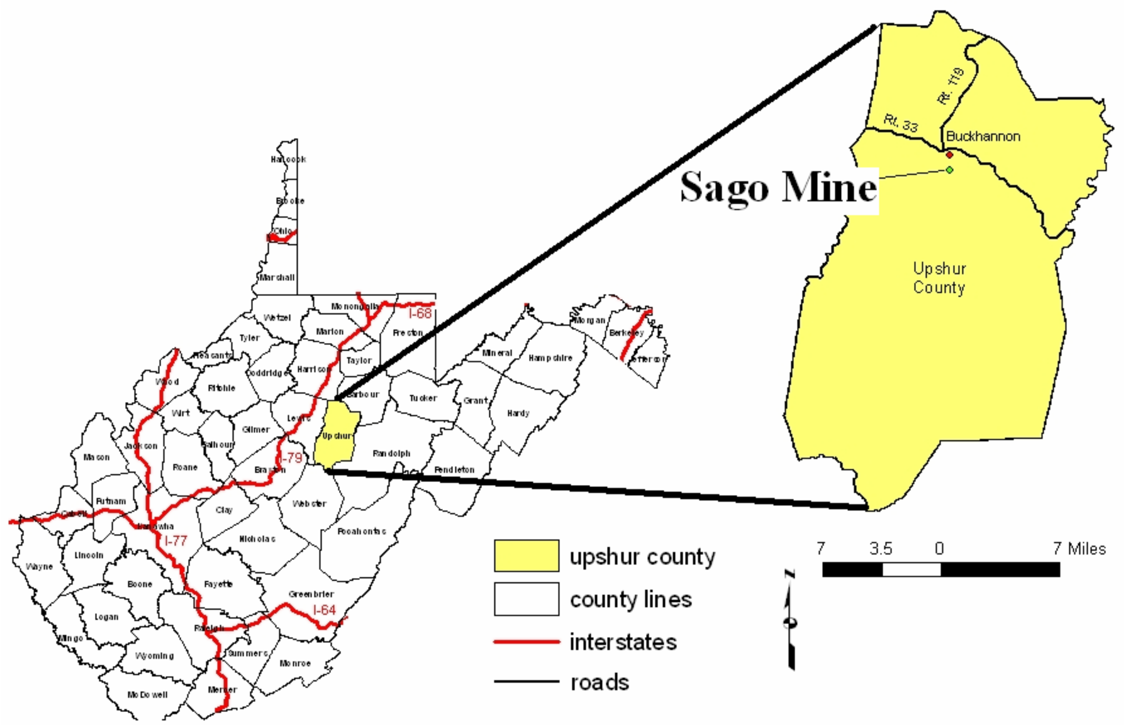
2.2 Report Preparation Process

2.3 General Acknowledgements

2.1 Description of the Mine

The unincorporated village of Sago is located in Upshur County, West Virginia. Upshur County covers an area of 350 square miles in north central West Virginia with gentle hills and streams.

This mine was first permitted as BJM Coal Company, Spruce No. 2 Mine, Permit Number U-2016-98 on 09/03/1999 and closed out on 11/26/2001. On 11/26/2001 the mine was permitted as Anker West Virginia Mining Company, Spruce No. 2 Mine, Permit Number U-2016-98A and closed out on 11/12/2003.



The Anker West Virginia Mining Company, Sago Mine, Permit Number U-2016-98B was issued on 11/12/2003 and is opened into the Middle Kittanning Coal Seam through (5) five drift type openings developed from a box cut type opening on the surface. The average coal seam height is 60 inches, however the mined height ranges from approximately 72 inches to (10) ten feet or more in some areas. This is due to both adverse roof and bottom conditions. The mine is usually very wet with soft bottom conditions.

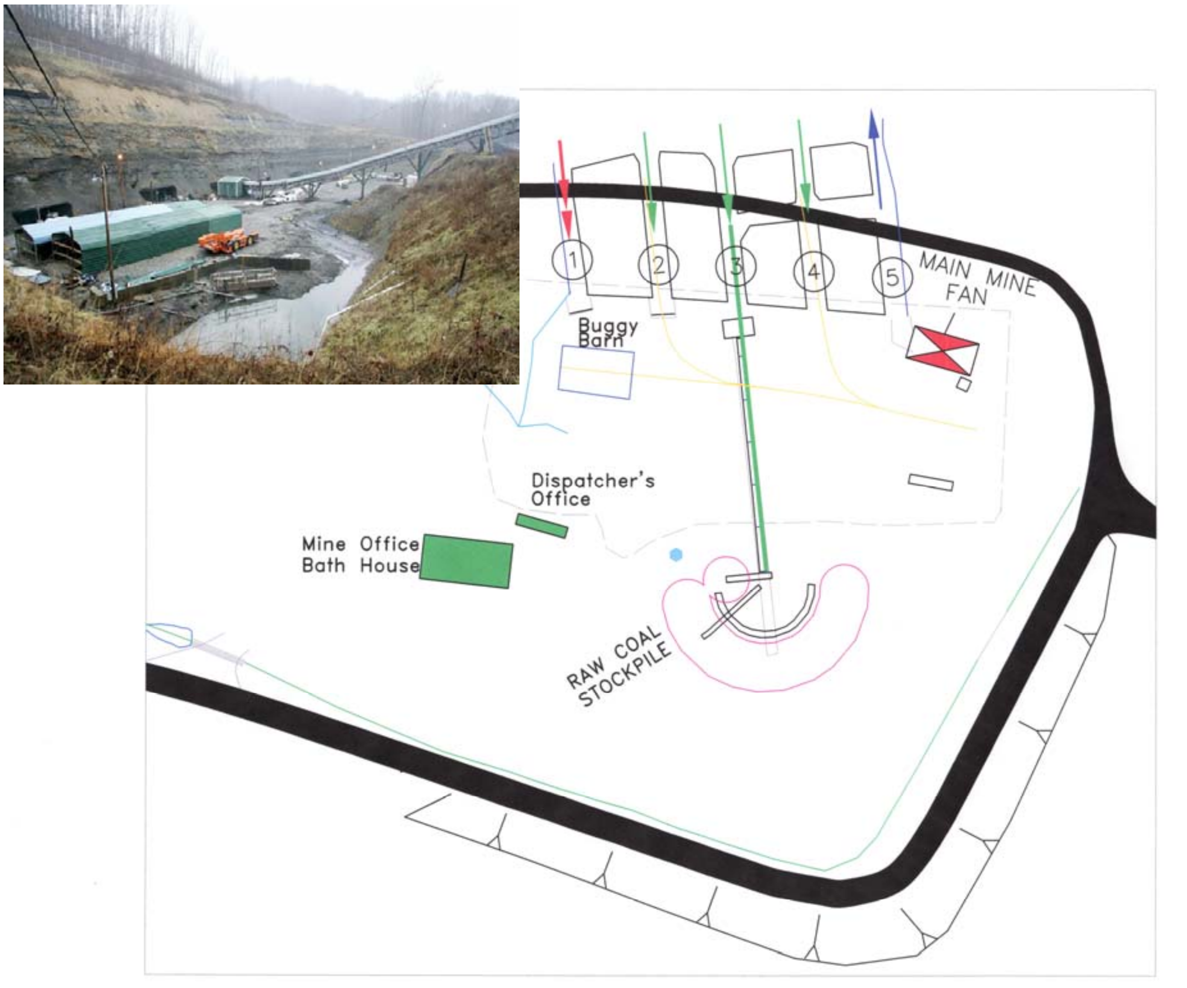
On May 12, 2006 this mine was re-permitted as Wolf Run Mining Company, Sago Mine, permit number U-2016-98C.

The mine is ventilated by a blowing fan located at the #5 drift opening producing approximately 168,162 cubic feet of air per minute. The working faces are ventilated using line curtains installed in a blowing ventilation manner so as to accommodate the scrubbers of the continuous mining machines. The mine liberates approximately 90,577 cubic feet of methane in a 24 hour period. Normally only 0.1 to 0.2 percent of methane is detected in the working faces.

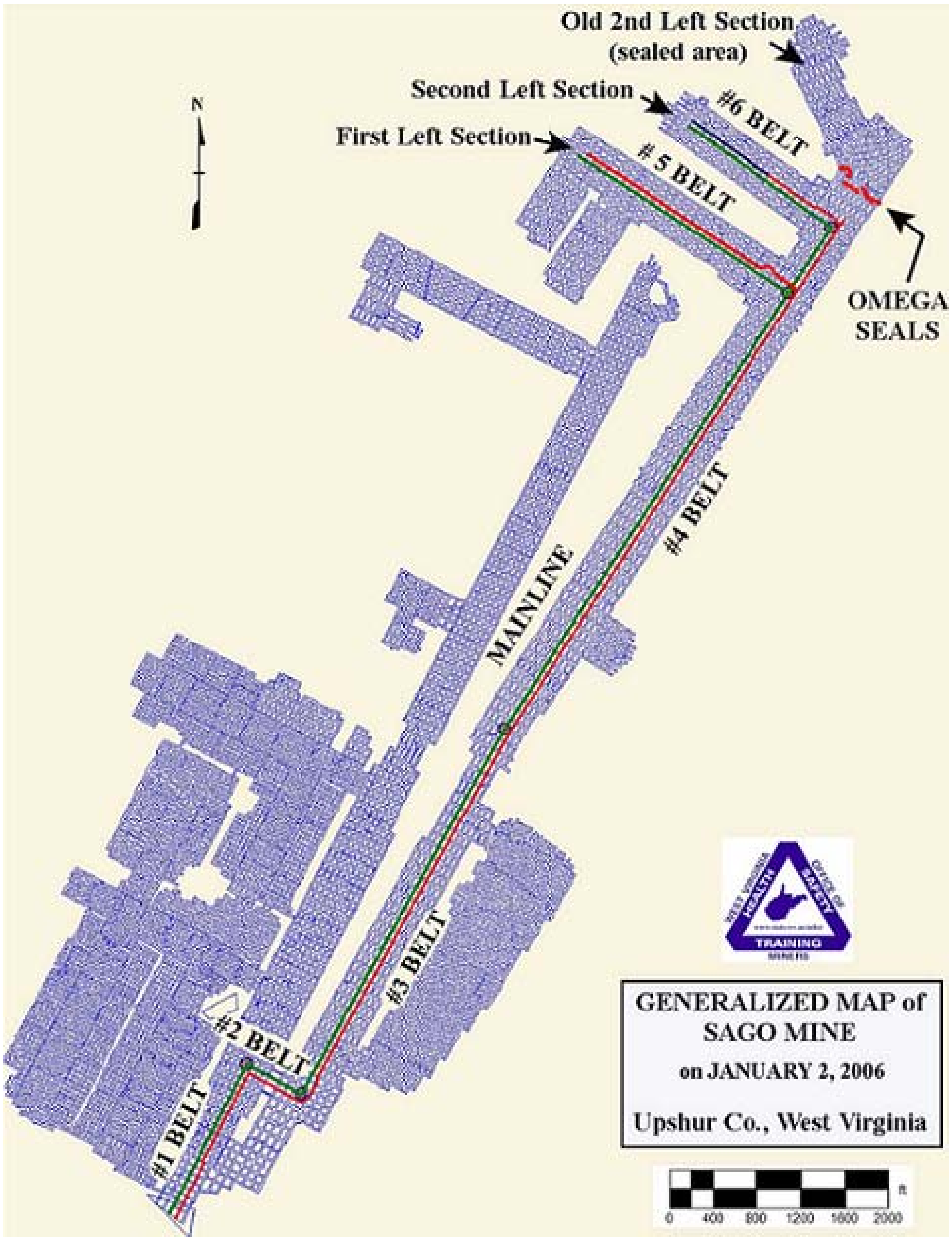
View of Sago mine portals to the left and the “hill” to the right with bathhouse and offices at far right.

The mine normally employs approximately 145 employees, works (2) two production sections, (2) two shifts per day, and (1) one maintenance shift Monday through Thursday and (1) one production shift and (1) one maintenance shift Friday through Sunday. The working sections are located approximately (2) two miles from the surface.

Coal is produced using remote controlled extended cut continuous mining machines, with shuttle car type face haulage. The coal is then transported to the surface via belt conveyors and removed from the surface of the mine by truck haulage. The roof is supported using dual head roof bolting machines and the roof supports usually consist of a combination of resin grouted rods, oversized plates, roof screen, rib tenders, cable bolts, and spider plates. Battery powered scoops are used on the sections and man-trip and supply haulage is accomplished by battery powered track equipment.



Sago mine pit area showing major structures discussed in the report.



Sago underground mine works with major features identified.

At this mine 492,507 tons of coal were produced during 2005, the mine worked 285,756 man-hours, sustained 14 lost time injuries and ended the year with a lost time frequency rate of 9.75 compared to a nationwide rate of 9.26 rate for underground mines.[1]

[1] Injury Experience in Coal Mining -2005, MSHA, page 263

MINE INFORMATION

COMPANY ANKER WEST VIRGINIA MINING COMPANY, INC

MINE NAME SAGO MINE PERMIT NUMBER U-2016-98B

ADDRESS RT. 9 BOX 507, BUCKHANNON, WEST VIRGINIA, 26201

COUNTY UPSHUR PHONE NUMBER 473-1676

DATE PERMIT ISSUED 11/12/2003 WORKING STATUS A

LOCATION 5 MILES SOUTHWEST OF BUCKHANNON NEAR SAGO

MINE FOREMAN CARL CRUMRINE CERT. NUMBER 25993

SUPERINTENDENT JEFFERY TOLER

NON-UNION X DAILY PRODUCTION 7000 TONS

ANNUAL PRODUCTION 2005 492,507 TONS

NAME OF COAL SEAM MIDDLE KITTANNING SEAM HEIGHT 60”

TOTAL NUMBER OF EMPLOYEES 145 SHIFTS 3

ACCIDENT FREQUENCY RATE 9.75 LOST TIME ACCIDENTS 14

TYPE OF HAULAGE BELT, SHUTTLE CAR, TRACK MANTRIP/SUPPLY

WV OFFICE OF MHST INSPECTOR JOHN COLLINS, DISTRICT INSP. #2

DATE OF LAST REGULAR INSPECTION NOVEMBER 2, 2005

DATE OF LAST CHECK INSPECTION DECEMBER 12, 2005

NOTIFIED OF ACCIDENT BY JOHN B. STEMPLE, JR.

DATE AND TIME OF NOTIFICATION JANUARY 2, 2006 AT 7:46 A.M.

CMSP ANNIVERSARY DATE OCTOBER 31, 2006

CMSP CONTACT PERSON JAMES A. SCHOONOVER, SAFETY DIRECTOR

2.2 Report Preparation Process

The report process began as soon as the West Virginia Office of Miners' Health Safety and Training (OMHS&T) was notified of the accident. OMHS&T personnel arrived on the site within minutes of being notified. Logs critical to the drafting of the report, were maintained throughout the rescue and mine recovery phases.

During the rescue and mine recovery OMHS&T, the US Mine Safety and Health Administration (MSHA) and the company - International Coal Group (ICG) participated as one team. Decisions were made by agreement and records kept.

After the mine was safe to enter teams were formed to collect evidence to help understand what had happened. Each team had participation from each organization and was often joined by representatives from the United Mine Workers. These teams focused on; overview, flames and forces, electrical, mapping, photography, records review, and rock dust. Separately the WV medical examiner developed a report on the victims. Also during this time, the process began of collecting sworn testimony of more than eighty individuals.

As the investigation teams completed their work they began the process of analysis within their area. At this point the ICG members' direct participation was reduced, and subject matter experts were brought in as government agencies began focusing on individual responsibilities.
With the bulk of the evidence collected synthesis and hypothesis development began. In this process evidence and initial analysis from multiple disciplines was correlated for relevance and initial hypotheses were developed, tested against the evidence and accepted or rejected. Both MSHA and OMHS&T are charged under law with conducting independent investigations. As a

result during this period the OMHS&T functioned predominately alone while reaching out to MSHA, NIOSH, ICG, and experts as needed.

The final stage of the process involves drafting documents and developing recommendations. This process called for the dedication of a core of the investigation team to focus exclusively on compilation of all that was learned into an effective narrative.

The Sago report does not follow the standard outline for OMHS&T accident reports. The magnitude of the accident, its complexity, and the massive investigative effort dictated a level of detail not normally associated with such reports.

It would be impossible to acknowledge all those who have contributed to information in this report. Of particular note must be Brian Mills, OMHS&T Inspector at Large for the region in which Sago lies, who led the effort for OMHS&T, John Collins the OMHS&T Mine Inspector normally assigned to the Sago mine was involved on a day-to-day basis as was Monte Hieb, the OMHS&T Chief Engineer, and John Scott, electrical inspector.

2.3 General Acknowledgements

The WVOMHS&T gratefully acknowledges the cooperation and efforts of the representatives of OMHS&T, Anker West Virginia Mining Company, Inc (ICG), Sago Mine, and the UMWA during this investigation. The WVOMHS&T also gratefully acknowledges the numerous others who have assisted, in so many ways, our efforts throughout the investigation.

This report prepared by:

John Collins, District Underground Inspector

John Cruse, Engineer

Randall Harris, Consultant

Monte Hieb, Chief Engineer

Dr. E. Philip Krider, Consultant

John Meadows, District Surface Inspector

Brian Mills, Inspector at Large

John Scott, Electrical Inspector

Ron Wooten, Director

December 11, 2006

3 MINE RESCUE

The discussion in this section does not attempt to draw conclusions. Conclusions can be found in the investigation sections that follow. Instead, this section attempts to present the facts, as determined by the investigators. The hope is that this section will provide insights, which will assist in making all mines safer.

This section has dozens of authors. The text is based on the notes and testimony of those involved. During the hundreds of hours spent preparing this section, over seventy transcripts were reviewed. Logs from the participants in the command center and most of the mine rescue teams along with technical reports from dozens of groups on hundreds of subjects were searched for facts and confirmations.

3 THE RESCUE

3.1 Day Shift

On Monday January 2, 2006, the day shift production crews for the first-left and second-left working sections were scheduled to start work at 6:00 a.m. Due to the New Years holiday, the mine had not produced coal[1] since 7:30 p.m. on December 30, 2005, when the afternoon shift ended. Only a small maintenance shift worked during the break.[2]

Before the arrival of the production crews at the mine, James Fred Jamison and Terry Helms, both certified pre-shift examiners, were required to complete their pre-shift examination[3] of the mine.

That morning Mr. Jamison and Mr. Helms planned to jointly examine the areas of the mine containing one-, two-, three-, and four-belts and tracks. Mr. Helms planned to then examine the first-left section including 5-belt and track. Mr. Jamison would then examine the second-left section including 6-belt and track.[4] The old-second-left seals were not part of the required pre-shift examination, rather were part of a separate weekly exam, last completed by John Nelson Boni on December 28, 2005.

William (Bill) Chisolm, dispatcher, directed people in and out of the mine, monitored communications and the belt system. Mr. Chisolm was also designated as the "Responsible

[1] Page 48 starting on line 12 of statement under oath of Carl Lee Crumrine February 16, 2006

[2] Statement under oath of Nathan Harold Eye February 17, 2006 – Mr. Eye is the dispatcher who worked the Friday, Saturday and Sunday shifts immediately prior to the January 2, 2006 shift. The carbon monoxide monitoring system records show that the belts were energized on January 1, 2006 at 09:42:27 a.m. then de-energized ending at 09:49:16 a.m. and not restarted until 5:27:16 a.m. on January 2, 2006 when they were again restarted beginning with one-belt through four-belt. There is no record of the belts in first-left or second-left having been started on January 1, 2006. On page 54 starting on line 11 of the statement under oath of Carl Lee Crumrin taken February 16, 2006 Mr. Crumrine indicates that fans had not been shut off at any time prior to beginning of the January 2 pre-shift.

[3] Prior to beginning any work underground West Virginia law requires that a designated mine examiner conduct a safety inspection of each area in which miners will be working.

Person"[5] charged with contacting others in case of an emergency[6]. Mr. Jamison and Mr. Helms notified Mr. Chisolm that they were entering the mine at 3:00 a.m.[7].

When he reached the mantrip at the head of five-belt, Mr. Jamison used it to travel to the track switch leading to the second-left section. At this location he left the mantrip and walked into the section where he conducted his examination at approximately 4:00 a.m.[8]. He estimated that he spent 25 minutes walking up to the section face, examining each entry and taking air readings, all of which indicated zero percent methane. He examined the rock dusting, location of equipment, and curtains and noted that there was lots of air movement at the faces. Mr. Jamison called the dispatcher to report that he was leaving the section at 4:35 a.m. and requested that Mr. Chisolm tell Mr. Helms that he would leave his lunch pail at the first-left track switch.[9]

After he completed his examination, Mr. Helms remained in the mine approximately 500 feet from the old-second-left seals near the number-six belt discharge. After making a stop to check for blockage in the number three-belt head and to turn on a pump, Mr. Jamison exited the mine shortly before 5:30 a.m. He parked the mantrip at a charger, since its battery was getting low, and proceeded to the foreman's office to report on his pre-shift examination.

The mine safety director, James Allen Schoonover, arrived on site around 5:00 a.m., checked his email and notes left by foremen and joined others arriving in the foremen's office to discuss any outstanding issues.[10] Mr. Denver Wilfong, maintenance chief, also arrived at the mine around 5:00 a.m. He reviewed notes from the previous shifts, until the production crews started to arrive. As they arrived, he helped them gather materials or parts that they would need during their shift.

The day shift production crews began arriving about 5:15 a.m. for their scheduled 6:00 a.m. start. The weather was unusual for the first part of January noted Mr. Schoonover, "…I went to the door

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[4] Statement Under Oath of James Fred Jamison taken January 17, 2006
[5] Defined at WV 36-5-2.2
[6] Statement Under Oath of William (Bill) Chisolm, February 15, 2006
[7] Statement under oath of William (Bill) Chisolm, February 15, 2006
[8] Statement under oath of James Fred Jamison taken January 17, 2006 taken by OMHS&T & MSHA
[9] Page 42, line 5 of Statement under oath of William (Bill) Chisolm February 15, 2006
[10] Statement under oath of James Allen Schoonover taken January 18, 2006 by OMHST&T and MSHA

and opened the door because it was lightning and thunder carrying on so bad and it was so warm for the second day of January."[11] [12]

Mr. Jamison reviewed his pre-shift report with second-left section foreman Martin Toler Jr.[13] Mr. Helms phoned his report to the surface at 5:25 a.m. from the second-left track switch phone.[14] The carbon monoxide monitoring system log indicated that Mr. Chisolm energized the belts from his control panel at 5:27 a.m. following receipt of the pre-shift reports.[15]

At approximately 5:30 a.m. Jeffery Keith Toler, mine superintendent, arrived on site and joined the others for the pre-shift meeting. After the production crews left for the mantrips he went to his office and began reviewing administrative reports. [16]

At approximately 6:00 a.m. the second-left crew entered the mine via a battery powered, track mounted man-trip. The crew was under the direction of Mr. Martin Toler, Jr., their Section Foreman and consisted of:

Alva M. Bennett,
Continuous Mining Machine Operator

Fred Ware, Jr.,
Continuous Mining Machine Operator

Jesse L. Jones,
Roof Bolting Machine Operator

David W. Lewis,
Roof Bolting Machine Operator

Jerry L. Groves,
Roof Bolting Machine Operator

Thomas P. Anderson,
Shuttle Car Operator

George J. Hamner,
Shuttle Car Operator

James A. Bennett,
Shuttle Car Operator

Marshall C. Winans,
Scoop Operator

Jackie L. Weaver,
Section Electrician

Randal L. McCloy,
Roof Bolting Machine Operator

[11] Page 24 line 25, Statement of James Allen Schoonover taken January 18, 2006
[12] The National Climate Data Center reports that the Buckhannon station located 5 mines northwest of the Sago site was reporting a storm passing in the direction of the mine at this time. Wind speeds increased from zero at 5:40 a.m. to 12 miles per hour at 7:40 a.m. then dropped back to zero by 11:40 a.m. The visibility dropped from 10 miles at 4:40 a.m. to 4 miles at 6:40 a.m. while humidity moved from 58 percent to 100 percent during the same period. Wind directions fluctuated during this period as well from 180 degrees to 100 degrees. http://cdo.ncdc.noaa.gov/ulcdsw/ULCD
[13] From statement under oath of Fred Jamison January 17, 2006 starting page 95
[14] Page 45 line 5 of Statement under oath of William (Bill) Chisolm February 15, 2006
[15] Sago's Carbon monoxide monitoring system printed reports indicate that the belts were de-energized starting with number four-belt and 9:48:58 and sequentially through one-belt at 9:49:16 a.m. on the January 1, 2006. The belts were next energized starting with the one-belt at 5:27:16 a.m. then sequentially through four-belt at 5:32:17 a.m. on January 2, 2006
[16] Statement under oath of Jeffrey Keith Toler January 18, 2006

Mr. J.N. Boni, a certified forman, received the pre-shift report from Mr. Helms in the foreman's office over the mine phone and wrote it in the book. He was supposed to ride in the mine on the second-left mantrip. He had a conversation with Mr. Jamison concerning a pump that would not start and, was therefore too late to catch the second-left mantrip. He decided to ride with the first-left crew, who had not yet left. However, there was not enough seating on the first-left mantrip for Mr. Boni, so they all switched to a larger mantrip vehicle. This delayed their departure by a few minutes.

The first-left crew and three passengers entered the mine under the direction of Owen Mark Jones, Section Foreman, a few minutes behind the second-left crew. This crew consisted of:

Gary Rowan,
Roof Bolting Machine Operator

Gary D. Carpenter,
Continuous Mining Machine Operator

Roger Perry,
Continuous Mining Machine Operator

Chris Tenney,
Equipment Operator

Paul Avington,
Equipment Operator

Joe Ryan,
Roof Bolting Machine Operator

Alton Wamsley,
Roof Bolting Machine Operator

Randy Helmrick,
Roof Bolting Machine Operator

Eric Hess,
Scoop Operator

Denver Anderson,
Scoop Operator

Hoy Keith,
Electrician

John Patrick Boni,
Belt-man

Ron Grall,
Mine Examiner

John Nelson Boni,
Pumper-Mine Examiner

At this time Mr. Jamison reentered the mine and walked to the number two-belt conveyor where he began his shift duties, monitoring belts.

Mr. J.N. Boni exited the first-left mantrip at the first-right track switch and checked the pump Mr. Jamison had reported would not start near 22-block, three-belt. He checked the pump, replaced a part, started it, and then began his rounds.[17]

[17] Statement under oath of John Nelson Boni taken January 19, 2006 by OMHS&T and MSHA

John Patrick Boni, beltman, exited the man-trip at the number four-belt drive. He was to work where the numbers three and four belts connect. Both belts were running when he arrived.[18]

The second-left crew arrived on their section and began to set up for work. The first-left crew was nearing the track-switch heading into their section. It was almost 6:30 a.m.

Shortly after the men entered the mine the weather turned worse. Mr. Chisolm, who was in the dispatcher's office, recalled "the wind was blowing and a heck of storm came through."[19] Around 6:25 a.m. Mr. Toler reported talking with Mr. Schoonover about the storm coming through and noting how unusual it was.[20] Mr. Toler was on the mine phone with Mr. Chisolm asking about the storm, when Mr. Chisolm commented on a flash of lightning that was immediately followed by a loud clap of thunder.[21] Mr. Chisolm reported at the exact moment of the lightening that his phone made a popping nose that hurt his ear and instinctively "…I threw the phone down…"[22] He picked the phone up and reported to Mr. Toler that "…there's something wrong. I have immediately lost all communication…as soon as it happened; I said I lost all the belts and everything."[23] Mr. Toler recalled, "I could hear the carbon monoxide alarms going off on the carbon monoxide monitoring system." By now Mr. Wilfong had joined them on the mine phone. "Our first thought was that the lightening had just shorted out the carbon monoxide alarms. They'll blow fuses on them,"[24] noted Mr. Toler. Mr. Wilfong pointed out that the monitors have only 250 milliamp fuses, "…we thought that fuses had blown, because that occurs during storms a lot."[25] At this point Mr. Wilfong gave Vernon Hoffer, maintenance foreman, who happened to be sitting in the office, a handful of fuses and told him to "…go down there and check the system and replace what fuses he needs."[26] Mr. Hofer gathered his light and headed toward a mantrip.

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[18] Statement under oath of John Patrick Boni taken February 20, 2006 by OMHS&T and MSHA

[19] Page 26 line 14 Statement under oath of William (Bill) Chisolm February 15, 2006

[20] Page 25 line 1 Statement under oath of Jeffery Keith Toler January 18, 2006 – also see footnote above regarding NOAA weather data

[21] Page 25 line 3 Statement under oath of Jeffery Keith Toler January 18, 2006

[22] Page 34 starting at line 2 through page 35 line 6 Statement of William (Bill) Chisolm taken February 15, 2006 by OMHS&T and MSHA

[23] Page 33 starting at line 15 Statement of William (Bill) Chisolm taken February 15, 2006 by OMHS&T and MSHA

[24] Page 25 line 18 Statement under oath by Jeffery Keith Toler on January 18, 2006.

[25] Page 41 line 2 Statement under oath by Denver Wilfong January 16, 2006

At approximately the same time the first-left crew was getting ready to turn from the main track onto the first-left track. The crew was in a straight line approximately 1,000 feet from the seals of old-second-left section. Just as Arnett Roger Perry sat back in the mantrip after throwing the track switch, "…here comes this hurricane of dust and rocks and no warning, no sound, nothing, just there out of nowhere." Mr. Perry continued, "…its blowing hard and you can't see through the dust and it blew my hat off, my light. And then it stopped and I said there's been an explosion guys."[27] Owen Mark Jones, first-left foreman, who was operating the mantrip, immediately stood up from his seat in the open center of the mantrip "… somewhere, somehow, and it blows me off the top of the mantrip, the wind does. And I'm standing there and it's pushing me forward. It's making me walk. And I'm thinking it's going to absolutely pick me up and throw me, and I mean, then it just quits." "There was no warning, no nothing, just was right there on us."[28] Eric Michael Hess noted, "I didn't hear an explosion, no boom, no nothing --- the only thing we heard was you could hear like when you run your car off the road and you hear gravel hitting underneath your car, you could hear that hitting the end of the mantrip and that's all we heard and just the wind was all we heard."[29] Then it stopped, "It was dead. Everything was completely dead. There was no sound. There was no wind. The dust and everything…it just hung there. There was no air, no nothing," noted Harley Joe Ryan.[30]

The blast of air was accompanied by dust, "I don't know if you've ever been in sandstorm, but that's exactly what it felt like. Somebody just took a handful of sand and threw into a fan and just --- you could feel it pelt you," noted Christopher Tenny.[31] The perceived duration of the air blast varied among the first-left crew. Gary B. Carpenter noted, "I couldn't tell you how long the explosion lasted, you know, because it seemed like, you know, a long time going through this, debris flying, hitting us, coal, mud, everything."[32] Mr. Tenny remembered, "It seemed like it

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[26] Page 41 line 2 Statement under oath by Denver Wilfong January 16, 2006
[27] Page 20 starting on line 16 of Statement under oath of Arnett Roger Perry, January 26, 2006
[28] Page 22 starting line 14 through page 23 line 6 of Statement under oath of Owen Mark Jones, January 17, 2006
[29] Page 36 starting at line 20 of Statement of Eric Michael Hess, February 14, 2006
[30] Page 44 starting at line 8 of Statement under oath by Harley Joe Ryan January 26, 2006
[31] Page 38 starting on line 9 of Statement by Christopher Tenney, January 23, 2006
[32] Page 22 starting at line 19 of Statement under oath of Gary B. Carpenter January 19th, 2006

lasted forever but, approximate to me, it lasted about five to ten seconds actually."[33] Mr. Jones in his debriefing after returning to the surface at 10:30 a.m. estimated the duration at 3 to 4 seconds.[34]

The first reaction of the crew was similar to that of Gary Rowan who stated, "…for the first couple seconds I thought we had a roof fall right in front of the mantrip. But then, you know, when it didn't quit and then after a few seconds, we felt the heat come across." "…It wasn't nothing that, I mean, would burn you or anything like that, but you could definitely tell there was heat coming off it."[35] The heat was accompanied by a smell, "It smelt --- kind of warm smell, kind of a burning smell," noted Mr. Carpenter.[36] Mr. Grall explained that "…when that heat hits you, you couldn't --- you didn't have any oxygen, you just couldn't breathe. It was very hard to breath. It made my heart --- my heart was pounding." [37]

At the same time the first-left crew experienced the blast, it was felt outby at the number four-belt drive, where J.P. Boni was servicing a trickle duster some 5,800 feet from the old-second-left seals. "I walked down the belt and had taken two steps and pop and just air hit me and dust."[38] The dust was sufficient to reduce Mr. Boni's visibility. He noted he could see, "probably 14, 15 feet or something like that."[39] Mr. Boni also noted that he "didn't smell anything, just covered with dust."[40] He further noted that the blast of air lasted "maybe a second and half or a second. It just hit me and that was it, it was over." The force was such that although he was facing into the path of the air, he stated, "it hit me in the face, but it really didn't get into my eyes."

Further from the old-second-left sealed area, some 7,600 feet away, was Mr. J.N. Boni who was working on pumps in the return at 22-block, three-belt. Mr. Boni related "The air came at me and hit me, and then kind of backed up like a small pillar fall would be." "…when I was in the return, I never saw any dust or anything. But when I walked back over --- I went through the man door

[33] Page 23 starting on line1 of Statement under oath of Christopher Tenny January 23, 2006
[34] Notes of John Collins OMHS&T District Inspector
[35] Page 45 starting on line 1 of Statement under oath of Gary Rowan February 15, 2006
[36] Page 45 starting on line 23 of Statement under oath of Gary B. Carpenter January 19, 2006
[37] Page 49 starting on line 11 of statement by Ronald Grall January 19, 2006
[38] Page 30 starting at line 11 of Statement by John Patrick Boni February 20, 2006
[39] Page 33 starting at line 1 of Statement by John Patrick Boni February 20, 2006
[40] Page 32 starting at line 22 of Statement by John Patrick Boni February 20, 2006

back over to the belt and track there it was real dusty, mostly rock dust. It was white dust." Mr. Boni walked to a mine phone and called Mr. Chisolm, the dispatcher, "…what's going on? And he said "a big lightening strike and we lost the power on three and four belts. He said one and two is still running." By this time there were other people on the mine phone. Mr. Boni then told Mr. Wilfong and Mr. Hofer to hold up on coming in to work on the belt system until he looked for a roof fall. Mr. Boni stated that "I walked up the track probably eight or ten blocks, then came back down the belt line and no fall, and he said, there might be fall on the line…" Mr. Boni heard his son J.P. Boni report heavy dust near his location some 1,800 feet outby, "I was figuring something else happened" "I called the dispatcher and asked him if any --- we had any CO detectors picking up CO. And he says yes, the second-left detectors are pegged. And at that time, I said we've had an explosion."[41]

At that point Mr. Toler and Mr. Wilfong, who had been monitoring the conversation in the office phone, broke in and asked Mr. J.N. Boni where he was. Just then first-left section foreman, Owen Jones, who was leading the first-left crew through the dust on foot, heard the voices on a mine phone. While he could not see the phone, he made his way to the sound and reported the blast that the first-left crew had just experienced. It was approximately 6:35 a.m.[42]

[41] Starting at page 24 line 10 of statement under oath by John Nelson Boni January 19, 2006
[42] Statements under oath of Jeffery Keith Toler, Denver Wilfong, John Nelson Boni, and Owen Mark Jones

3.2 Initial Response

Upon hearing the report from the first-left crew and others, Mr. Toler instructed Mr. Jones to get his men into the intake escapeway and start exiting the mine. Mr. Toler related that while this was going on "…my thoughts were, you know, we hadn't heard from the second-left crew at all." Mr. Toler, Mr. Schoonover and Mr. Wilfong got their gear and headed for the mine entry. Along the way they were joined by Mr. Hofer. They entered the mine at approximately 6:45 a.m.[1]

After the blast Mr. Jones "…requested everybody to stay in one spot until he got a head count to make sure everybody was there and everybody was okay and able to move." "At that point, we more or less kind of grabbed onto each other, because you couldn't see until we found the rib, we felt our way down the rib" related Mr. Tenny.[2] Mr. Jones directed the crew outby with the intent of crossing into the intake escapeway, where they expected to find clean air. The nearest mandoor was approximately 150 feet outby at 48-block four-belt, "…we went through the mandoor and the intake escapeway looked just like the track. Of course at this time we did not know that the stoppings outby had been blown out" related Mr. Hess[3]. As they proceeded in near zero visibility they felt their way by reaching for the ribs and holding on to each other, "you couldn't see your feet, so you just had to put your hands --- you know, we were --- everybody was just about close enough where you could keep --- you know, grab a shirt or belt or a belt loop or something, just so everybody could stay kind of together" remembered Mr. Hess.[4] The crew searched for a way to the intake escapeway "and every time we'd look for a mandoor, a place to go in the intake, the stopping would be gone, it was blown out. So we finally did go into it and started down. It started to clearing up a little bit" related Mr. Perry.[5]

[1] Statements under oath of Jeffery Keith Toler, Denver Wilfong, John Nelson Boni, Owen Mark Jones, James Fred Jamison, and James Allen Schoonover
[2] Page 40 starting at line 4 of the statement under oath of Christopher Tenny January 23, 2006
[3] Page 24 starting at line 2 of statement under oath of Eric Michael Hess February 14, 2006
[4] Page 41 starting at line 4 of the statement under oath of Eric Michael Hess February 14, 2006
[5] Page 21 starting on line 16 of the statement under oath of Arnett Roger Perry January 26, 2006

Some of the first-left crew donned their self-contained self-rescuers at once "…someone said let's get our rescuers on, you know, and all --- about some, two or three I think said that, you know, and we pulled them and put them on" remembered Mr. Anderson. [6] However, others waited, thinking that they would find fresh air in the intake, "…when we went through the mandoor (at 48-block four-belt) and saw that there was no fresh air there, that's when we put our self rescuers on" said Mr. Hess[7] Some of the first-left crew never donned their self-rescuers. Even though his detector was alarming carbon monoxide and low oxygen, Mr. Grall said "I figured as long as I could breathe, I wasn't putting mine on. And Paul Avington asked me if we should go ahead and put them on. I said, not yet, because I was trying to get the fresh air. We should have probably put them on."[8]

While making their way inby Mr. Toler, Mr. Wilfong, Mr. Schoonover, and Mr. Hofer encountered, separately, Mr. Jamison and Mr. J.N. Boni. After making sure they were okay they instructed Mr. Jamison, and Mr. Boni to continue out of the mine. Near 35-block, four-belt they stopped at a mine phone to check in and determine if there had been any contact with the crews. As they were talking on the mine phone the first-left crew heard them as they were passing the same block in the intake. One of the first-left crew came through a mandoor at 37-block four-belt and said one of the crew was having trouble. Since the air was clear in the track Mr. Toler instructed the first-left crew to cross over and had them load up on the mantrip. Mr. Wilfong was on the phone and instructed Mr. Chisolm to call for "…mine rescue and notify both agencies that we had an explosion, because those guys (first-left crew) were covered in smoke and told me what had happened."[9] The dispatcher then connected an outside call with John B. Stemple, assistant director of safety and employee development, to Mr. Toler through the mine phone[10]. At that point Mr. Toler instructed Mr. Stemple to "…notify mine rescue…" and instructed him to stay at home making all the calls. He later noted that that was a smart move as it expedited logistics, not

[6] Page 35 starting on line 6 of the statement under oath of Denver Anderson February 14, 2006
[7] Page 24 starting on line 8 of statement under oath of Eric Michael Hess February 14, 2006
[8] Page 69 starting at line 1 of statement by Ronald Grall January 19, 2006
[9] Page 62 starting at line 12 of statement under oath of Denver Wilfong February 16, 2006
[10] While the mine phone does not have the ability of make outside calls the dispatcher had the ability to manually connect an already established call through to the mine phone system.

having that person caught up in the dynamics at the mine. Mr. Toler then instructed Mr. Wilfong to take the first-left crew to the surface. It was approximately 7:00 a.m.[11]

The first-left crew also informed Mr. Toler that Mr. Jones had gone back inby. After he was sure his men were in the intake escapeway Mr. Jones told Mr. Grall that "I'm looking to see that we got everybody. I'm telling my men, I said, you men get out of here immediately. Get going down the intake. I said I'm going to stay in here and see what I can do because I got a brother up here. And I know --- you know what I mean, I'm thinking that they're still trapped up there somehow, someway. My men beg me to go with them, but I said no, you all go. I said I got to go see if there's anything I can do."[12]

Randal L. McCloy, the sole survivor of the second-left crew indicated that they had gotten out of their mantrip and had started to walk up to the face when the explosion occurred. This is compatible with the fact that the crew had not called into the dispatcher to report they were at the section yet. Drill steels were found near the face that had been brought from the surface with the men.[13] It is also compatible with the recollection of the first-left crew that the second-left mantrip was five to ten minutes ahead of them because they changed mantrip units.

As described by Mr. McCloy the force of the air blast at the second-left face was not sufficient to knock people down. When asked "Did it knock you over?" he responded "No, no. It wasn't that --- it was just like wind, you know."[14] Mr. McCloy did not recall the single[15] initial air blast containing smoke or dust "…the time that I seen the smoke was the time that --- actually, that we had went back to the face, where we hung curtain to try to escape the gas."[16] When asked about the density of the smoke he noted that "…because there were so many stoppings knocked down, it actually did kind of change. It kind of took everything, the air, into a circle, so it never did actually

[11] Statements under oath of Jeffery Keith Toler, Denver Wilfong, Owen Mark Jones, and James Allen Schoonover
[12] Page 25 starting on line 7 of statement by Owen Mark Jones January 17, 2006 taken by OMSH&T and MSHA
[13] Page 41 line 2 Statement under oath by Denver Wilfong January 16, 2006 taken by OMHS&T and MSHA
[14] Page 13 line 18 of statement under oath by Randal McCloy June 19, 2006 taken by MSHA - OMHS&T was not provided advance notice of the interview and has subsequently been unable to schedule an interview to ask further question.
[15] Page 18 line 20 of statement under oath by Randal McCloy June 19, 2006 taken by MSHA
[16] Page 15 starting on line 2 of statement under oath by Randal McCloy June 19, 2006 taken by MSHA

leave. So you know, it was just --- stayed right there. No one really knew what to do because it was just confused."[17] This is consistent with the description of the movement of the smoke and dust by Mr. Toler, when he was at 59-block of number four-belt, near the second-left section entry.

After the blast the second-left crew attempted to leave on their mantrip, but were turned back by debris on the track, as related by Mr. McCloy. Their way was blocked by debris "…something that was definitely in the way. I don't know if the structure --- I don't know what it was. It was just kind of --- some kind of structure."[18] They then drove back inby to 12-block, six-belt where the mantrip was abandoned. The crew exited and apparently walked inby for one crosscut before crossing to the intake escapeway. The damage to stoppings in this area and the large amount of debris likely contributed to the difficulty of their progress. Since many stoppings were destroyed, it is likely that the air quality was the same in all the entries. The covers for the self-rescuers were found near 12-block, of six-belt, in a crosscut to the intake escapeway. The arrangement of the covers indicated that the visibility was such that the crew gathered in a circle as they donned their units. By this time, the crew would have traveled outby in the mantrip and back. They then walked approximately 1,000 feet in air with potentially high carbon monoxide levels before donning their units. When the first borehole allowed sampling of the second-left area, carbon monoxide was 1,280 ppm. This was almost 24 hours after the explosion. It will never be known what the levels were before they donned their self-rescuers.

While he is unclear of the location at which the self-rescuers where donned, Mr. McCloy stated that the attempt to walk out was aborted by the section foreman because three of the twelve rescuers were not functioning "…this isn't safe like this. Let's go head back to the section." [19] According to Mr. McCloy the second-left crew then returned to the face and built a barricade of curtain material to protect themselves from the dust and smoke.

Meanwhile in the main intake escapeway inby 37-block, four-belt, Mr. Toler and Mr. Schoonover spotted Mr. Jones, first-left section foreman, who had stayed in the mine, after sending his crew

[17] Page 19 starting on line 1 of statement under oath by Randal McCloy June 19, 2006 taken by MSHA
[18] Page 42 starting on line 8 of the statement by Randal McCloy June 19, 2006 taken by MSHA
[19] Page 30 starting on line 25 statement under oath by Randal McCloy June 19, 2006 taken by MSHA

outside. Mr. Toler recalled, "I noticed he didn't have a hard hat. He had lost his hat in that --- in whatever happened. So I told him to just stay right there by that telephone…me and Mr. Schoonover would go up and assess the damage."[20] After assessing some of the damage they called outside and instructed Mr. Wilfong and Mr. Hofer to bring materials to erect temporary stoppings and extra self-rescuers. The three men sat down and waited. With great urgency, Mr. Wilfong and Mr. Hofer had the surface crew load a vehicle with stopping materials, tools, and other equipment and headed back into the mine. Once Mr. Wilfong and Mr. Hofer reached Mr. Toler and Mr. Schoonover, the four of them and Mr. Jones, started working their way inby, hanging curtains as they advanced. "We trammed inby the 42 (42-block, four-belt), and started picking up some --- the carbon monoxide alarms --- some of the carbon monoxide alarms was starting to go off. So we made the decision to leave the mantrip there. We de-energized it." "So from 42 we were on foot… but gradually we worked our way in, keeping fresh air on our backs." When the group reached 50-block, four-belt which was adjacent to the first-left track switch, "I noticed the overcast at that point was damaged, so --- and I knew that everybody that we were looking for was on second-left. So we put up a solid curtain up there as well to direct all of the air current toward the second-left panel."[21]

As the group worked its way inby they reached the 57-block, four-belt only some two-hundred feet from the mouth of the second-left section. Mr. Toler, Mr. Schoonover and Mr. Wilfong were together as Mr. Jones and Mr. Hofer had been sent to recheck the areas outby this point for any missed damage. Mr. Jones related that Mr. Toler tells "you stay here." He says, "I don't want you going up there. I know why he's saying that, in case my brother is up there and he didn't want me seeing. I'm thinking to myself, I don't want to see this either." At 58-block, four-belt "…the smoke at this point was extremely dense. And our eyes, it seemed that the smoke was just kind of swirling, that it wasn't wanting to dissipate, but knowing now what I know, I think what it was, it was dissipating, but it was just continuing to roll out of the panel, and it was dissipating. Mr. Schoonover and Mr. Wilfong, both with mine rescue training, became concerned "if there is something in here that could still --- the potential to still explode, we may be pushing fresh air

[20] Page 31 starting at line 8 of statement under oath by Jeffrey Keith Toler January 18, 2006
[21] Statement under oath of Jeffrey Keith Toler January 18, 2006

overtop of a possible explosion and creating another explosion." [22] "I don't have any idea how long we stayed there and wrestled with it" "We would listen. You would hear something fall, and when I did, I would yell as loud as I could in that direction. Maybe we were hearing somebody moving…" "And with the smoke and stuff as heavy as it was and the damage that I saw, the place was devastated. I didn't think we could get any further. One of us would go down. We were going to have to --- well, I knew we were going to have to put our self-contained self–rescuers on. And we didn't have but a couple extras with us. And there were three of us there at that time, after Owen Jones and the others had gone out. And I knew if we put those --- if we all put our rescuers on and tried to go in there with no line or no ways to communicate other than hollering at each other, that we would --- somebody would --- maybe all of us would perish or one of us, at least. I was concerned about that. I told Jeff that we didn't know what we had. You couldn't see where the damn --- you know, you couldn't see to go" [23] "…but finally we just needed to go…to back out and let the professionals come in, people that were trained in this. So we made the decision to leave the mine. I stopped by the phone on the way out…to let people outside know that we had decided to leave."[24] The time was 9:30 a.m.

By that time John Collins District Inspector for the West Virginia Office of Miners' Health Safety and Training was on site and had issued a control order … the next phase of the rescue was poised to begin.

[22] Page 28 starting at line 2 from statement under oath by Owen Mark Jones January 17, 2006
[23] From statement under oath of Denver Wilfong February 16, 2006 starting on page
[24] Starting on page 30 of the statement under oath of Jeffery Keith Toler January 18, 2006

3.3 Joint Response

At 7:46 a.m. a call was placed to the home of John Collins. Mr. Collins is the District Inspector with the West Virginia Office of Miner's Health, Safety and Training (OMHS&T) assigned to the Sago mine. While Mr. Collins' phone did not ring, his message recorder started, and his wife heard John Stemple, safety director for Sago leave the following message:

> *"Hey John Collins this is Johnny Stemple it's about 15 till 8 Monday morning we have got a situation up at Sago mine where we have men underground that we have not been able to get a hold of and it's been more than 30 I mean more than 60 minutes. I have tried to get a hold of Mark Wilfong and no answer, I have tried to get a hold of Brian Mills and the number I have for him is listed as disconnected and you are next on my list. We don't know anything at this time. At 6:30 when the power went off, which is probably why I can't get a hold of you probably because your phone is out when the power went off we have not been able to get a hold of one of our crew underground so we are trying to get to that crew right now. It has been more than 60 minutes my home phone number is …"* [1]

Mr. Collins immediately returned the call and was briefed on the situation. After discussing the situation with Mr. Stemple for just a few moments Mr. Collins told him that he was going to the mine, and consider that the State had been notified. Mr. Collins phoned Brian Mills, OMHS&T Region One Inspector at Large, and left for the mine arriving at 8:15 a.m. Mr. Mills contacted OMHS&T Inspectors Barry Fletcher and Jeff Bennett directing them to assist Mr. Collins.

Upon arriving at the mine, Mr. Collins met with Charles Dunbar, Sago General Manager, and Carl Lee Crumrine, Sago General Mine Foreman, both of whom had arrived shortly before. The three began to organize efforts to secure the area, verify who was in the mine and begin collecting air measurements at the return. Mr. Collins joined the first-left crew to gather as much information as he could. The first-left crew was being examined by EMT's and volunteer firemen[2] who had just arrived, and oxygen was being administered to several people, who were having trouble breathing. Mr. Collins then attempted, unsuccessfully, to contact MSHA. It was approximately 8:15 a.m.

Mr. Fletcher arrived at 8:20 a.m. and Mr. Collins asked him to work with the Sago staff to secure the site and keep non-essential persons out. Mr. Bennett arrived at 8:23 a.m. and was asked to work on collecting the names of everyone on site and determine whether they were underground or on the surface. Mr. Bennett also initialed, dated and timed all entries into the record books.

Based upon what he had learned Mr. Collins issued a control order[3] to Mr. Crumrine requiring that as of 8:30 a.m. January 2, 2006, the Sago mine was closed, and that prior approval must be requested and given before any other underground activities could take place.

At approximately 8:30 a.m. James Satterfield MSHA Bridgeport Field Office Supervisor was reached by Mr. Stemple and informed of the accident.

Having gathered the initial facts, at 8:37 a.m. Mr. Collins talked to Doug Conaway, OMHS&T Acting Director, who was in route to the mine and provided him with an update.

Mr. Toler called from near the first-left track switch and requested that Mr. Crumrine enter the mine and work on the ventilation to get more air to the face, however, Mr. Crumrine remembered Mr. Collins advising, "…anything you do might hurt these guys, not help them." "I tried to call

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[1] Transcript on message left on Mr. Collins home answering machine.

[2] Page 31 starting on line 10 of statement under oath of Carl Lee Crumrine February 16, 2006 and treatment is confirmed in many of the statements of the first-left crew

[3] WV §36-19-7.1 stipulates that unless granted permission by OMHS&T, no operator may alter an accident site or an accident related area until completion of all investigations pertaining to the accident except to the extent necessary to rescue or recover an individual, prevent or eliminate an imminent danger, or prevent destruction of mining equipment

Jeff. I called inside --- I tried calling him. I couldn't contact him."[4] The time was approximately 8:45 a.m.

Mr. Crumrine remembers trying to get hold of those in the mine "…I put somebody in charge of calling every five minutes…trying to get hold of Mr. Toler…I think it was Mr. Chisolm, but…I don't remember who."[5] At this point Mr. Toler and the four others with him were inby the first-left track switch, beyond which there were no working phones. It was not until they returned to this point after abandoning their advance that they were able to make contact with Mr. Collins on the surface. At 9:30 a.m. Mr. Toler called outside and reported to Mr. John Collins that they had made it to 58-block, four-belt, but had encountered heavy smoke and soot. He also indicated that their detectors had burned up, and that there was not enough air to move the smoke. Mr. Toler stated that they were coming outside via the intake escape-way because the smoke and dust had now traveled outby in the track entry. [6] Mr. Hofer and Mr. Jones had already started out-by in the intake escape-way looking for damage to the ventilation controls. Mr. Toler, Mr. Schoonover and Mr. Wilfong caught up with these two men at 12-block, four-belt, where they were repairing an overcast that had been damaged during the explosion. The damaged overcast was allowing intake air to short circuit. Temporary repairs were made to the overcast and the men continued outby in the intake escape-way, arriving on the surface at 10:30 a.m.[7]

With multiple aspects of the response happening in parallel, it is difficult to provide a perfect chronology of activities. After the first-left crew, outby personnel and those that participated in the initial response were out of the mine, the focus was then on assessing the risks that the mine rescue teams would face. Coordinating the logistics of all the resources required to support the rescue was also a major focus.

At this point principal Sago management along with seven OMHS&T inspectors were on site. Multiple mine rescue teams were in route, local ambulances were on site and two of the first-left

[4] Page 37 starting on line 17 of statement under oath of Carl Lee Crumrine February 16, 2006
[5] Page 41 starting on line 1 of statement under oath of Carl Lee Crumrine February 16, 2006
[6] Page 102 line 1 of the statement under oath of Jeffery Keith Toler taken January 18, 2006 by OMHST&T and MSHA
[7] OMHS&T Inspector's timeline

crew had been transported to the hospital. The Red Cross had been contacted to assist with families, victims, and responders. MSHA had been contacted and their personnel were in route. The Upshur County Sheriff's Department had been requested to secure the entrances to site. At the same time the engineering firm for the mine was working on more maps for use by the command center and the rescue teams. Air sampling at the mine portal was showing levels of carbon monoxide increasing from 47 ppm at 8:40 a.m. to 505 ppm at 10:27 a.m.

MSHA personnel began arriving shortly after 10:30 a.m. Mine rescue teams began arriving at 10:45 a.m., beginning with the Barbour County Mine Rescue Team and followed throughout the day by others. The teams began setting up near the bathhouse. Monitoring of air at the mine portal continued to show increased levels of carbon monoxide. At 12:12 p.m. the measurements which had been near 500 ppm jumped to 2,000 ppm. As a precaution, the bathhouse area was evacuated in case these readings warned that a potential danger existed to the bathhouse. Over the next several hours, the readings remained at or near this higher level. Methane remained below 1.0 percent. At 1:00 p.m., the OMHS&T control order was modified to allow for the installation of a monitoring tube inby in the number one entry.[8] This was accomplished by one of the mine rescue teams.

Simultaneously OMHS&T inspector John Meadows was working with the company and a local drilling company in an effort to determine locations for boreholes, which would be used for sampling the mine atmosphere and supporting rescue options. Mr. Meadows contacted Mike Ross, who obtained the services of four drilling companies. While Mr. Ross was arranging the drilling rigs, permission was secured from landowners for surface access above the mine to construct emergency access roads and level pads for the drill rigs. OMHS&T Chief Engineer Monte Hieb arrived to assist in the final borehole placement. Based on information provided by the first-left crew and those that advanced to 58-block four-belt, it was decided that drilling would first commence into the second-left section near the belt feeder. The entry at that point is approximately 20 feet wide and was located approximately 260 feet below the drill point.

The location of the second-left drilling pad was first determined by using mapping-grade GPS devices that have an accuracy of approximately three to nine feet. By the time a dozer arrived at 5:00 p.m. a road into the wooded area and a pad had been staked out.

The pad upon which the drill rig would sit had to be on cut into solid ground. If the ground were soft, the drilling rig's vibrations would cause it to settle thereby moving the drill off perfect level. If that were to happen the borehole could miss the entry, end up in solid coal and be of no use.

The mapping-grade GPS location had to be refined by using a survey-grade GPS to ensure that the borehole location was accurate. A call was placed to Alpha Engineering Services, the contract surveyor for the mine, to provide a higher accuracy location for the borehole.

Gary Hartsog, Alpha President, was in Atlanta at the time of the explosion. When contacted by cell phone, he in-turn could not reach his surveyors to respond. Mr. Hartsog arranged to contact Marshall Robinson who had done surveying at the mine until August, 2005. Mr. Robinson had been without cell coverage, hosting visitors at the time of explosion. He just happened to stop by his office at 3:30 p.m. to check on things, and returned the urgent call left by Mr. Hartsog. Mr. Robinson immediately contacted several other surveyors from around the state who gathered equipment and headed to the mine. Those who responded were able to bring state-of-the art GPS and surveying software. Mr. Hartsog maintained in contact via cell phone throughout the night and the next day.

To achieve the fractional inch accuracy needed for the borehole, the group had to first calibrate the survey-grade GPS unit's reading to that of a known location. Fortunately those who arrived happened to know the location of permanent monuments (survey reference points). Two points at the mine mouth and one at a mine five miles away were checked against the survey-grade GPS readings. Correction factors were used to calculate the exact location of the borehole at second-left. To save time, an attempt was made to use direct radio linkage between the survey-grade GPS

[8] Covered in state order with this date and time issued by Mr. Collins and the action taken is described in the notes from Jeff Rice in his description on the activities of the Barbour County Mine Rescue Team

units on the monuments and the one near the drill site. However, the weather and local terrain limited radio communication. The correction factors had to be driven to the drill site. Because the terrain and trees limited line-of-sight for satellite access at the drill pad the last several hundred feet had to be done by conventional surveying from a point located in a clearing. Four hours after arriving on site at 11:30 p.m. the final stake was set. The mapping-grade GPS had been off by approximately thirty feet requiring the pad to be enlarged. Drilling began on the second-left borehole at approximately midnight. The proposed penetration point into the mine was near the center of the entry. Working from the tailgate of their pickup truck, the survey and drill teams had targeted this location on their computer.

Carbon monoxide readings at the portal continued to be high, but had begun to decrease, dropping steadily from 2,252 ppm at 4:00 p.m. to 1,662 ppm at 5:20 p.m. Methane had also dropped and was reading 0.3 percent. Approval was given for the first mine rescue team to begin exploration of the mine at 5:20 p.m.

For their own protection mine rescue team members must be privy to as much information as possible from the command center. A coordinated process has evolved to balance an understanding of the overall effort from the command center to those teams in the mine. During a rescue there is always one team on the surface ready to go in, one at the last point that fresh air has been established (the fresh air base) and one team exploring. As the mine rescue teams advance in leapfrog manner, new teams were rotated to replace those that come out.

The first mine rescue team entered the mine at 5:25 p.m. The team methodically advanced while maintaining contact with the command center through a combination of handheld radios, messengers, and the mine phone system. The team read 1,749 ppm carbon monoxide on the return-entry and zero percent methane on the track-entry. After advancing approximately 2,000 feet in the intake escapeway to the number three-belt drive they found 33 ppm carbon monoxide in the track entry and 17 ppm in the belt entry. No methane was detected in either entry. It had taken them 25 minutes to cover this 2,000 feet. This pace would prove to be one of the fastest, as mine rescue is tedious business. The next 900 feet required 30 minutes. At the 8-block, three-belt the carbon monoxide had increased to 565 ppm in the belt-entry. By 8:25 p.m., the working team had reached 28-block three-belt, 4,700 feet into the mine and almost 7,800 feet from the second-left crew. They were reading no methane and 4 ppm carbon monoxide at this point.

Behind the mine rescue teams in fresh air, a mine crew reenergized a pump near the number two-belt drive. There had been a concern that due to the dip in the mine at that location, flooding could compromise the integrity of the return. Because there was not sufficient information on the mine atmosphere to ensure that such action would neither trigger a secondary explosion nor expose the personnel reconnecting the pump to hazards, it was decided to wait until the mine rescue teams had been able to advance sufficiently beyond that point to determine if such risks existed..[9]

On the surface additional rescue teams had arrived. The OMHS&T mine rescue truck with its spare equipment and facilities for recharging rescue air packs was then fully functional. The command center was staffed by representatives from the company, the OMHS&T, and MSHA. The drilling activity made progress. The drillers had been told to stop drilling 20 feet above the top of the mine roof. This direction was given in order to give the command center time to order the mine rescue teams out of the mine. There was concern that as the drill penetrated the roof it may encounter methane that could cause a secondary explosion. While the first drill rig was working, locations for the second and third boreholes had been determined. Site preparation was begun.

As January 3, 2006 began, one mine rescue team had reached 8-block, four-belt and for the first time light smoke was reported. The team also observed damage in the form of a 2-foot by 10-foot hole in overcast. Carbon monoxide here was 1,000 ppm in the return and methane was 0.5 percent. The rescue teams were almost halfway to the second-left section, some 6,900 feet into the mine with 6,400 feet to go. It was 12:15 p.m., 18 hours since the explosion.

Based on apparent high concentrations of carbon monoxide, and evidence found with the second-left crew as well as reports from the medical examiner, it appears that only Randal McCloy survived until January 3.

Led by their section foreman Martin Toler Jr.,[10] the second-left crew made an unsuccessful attempt to exit the mine on their mantrip. They backtracked, and then walked to the intake escapeway covering an estimated 2,000 feet[11] before they donned their self-rescuers. The crew then attempted to walk out, as witnessed by footprints found in the dust by the rescue team. Finding their way blocked by smoke and debris, the crew was forced to return to the face, gathering materials to build a barricade as they went.

At the face they erected curtains across number three entry, providing a shelter against the dust and smoke. According to Mr. McCloy, It was a good location with enough room and with curtains and tools close by. The barricade provided some protection, "It kept a lot of smoke out, but I guarantee it didn't do too much on gas." The smoke that was behind the curtain hung in the still air "…for a short period of time and then it just faded out because no air was moving in there…"[12] After the barricade was erected all 12 of the second-left crew were inside; however, occasionally members would venture out to check conditions and look for the rescue teams.

Those inside the barricade used a sledge hammer to hit roof bolts in the roof of the crosscut just outby the face entry, in an attempt to signal surface seismic listening equipment. The MSHA seismic truck was not deployed. The procedure that is prescribed for the MSHA seismic location system is to wait for a signal from the surface, then respond by hitting a roof bolt. The miners obviously expected that someone would be listening.

Mr. McCloy reported that there were too few self-rescuers to go around, since four miners had been unable to make theirs work.[13] Those who had working units shared with those next to them. Mr. McCloy reported trying to assist Jerry L. Groves with getting his SCSR started "…we tried to

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[9] Request for modification to control order number one and resubmitted as number seven along with discussions with Mr. Mills and Mr. Collins.
[10] Page 31 starting on line 17 of the statement by Randal McCloy June 19, 2006 taken by MSHA
[11] Distance from face to end of track then forward to assumed furthest point driven then back to where the mantrip was found then to the point where all the covers for the SCSRs were found
[12] Page 43 starting on line 23 and page 44 line starting on line 21 of the statement by Randal McCloy June 19, 2006 taken by MSHA
[13] Section 5.6 of this report covers SCSRs in greater detail

get it working, and it didn't work" "…it aggravated me the most because really I wanted his to work." "I fought with it for I don't know how long, trying to mess with that valve, blow air through it or anything I could do, but nothing would work."[14] In addition to sharing units, the miners who did have working units took them off when building the barricade and to talk to each other which required that they be removed. The cumulative exposure to carbon monoxide before, during, and after their SCSRs apparently stopped producing oxygen exposed the individuals to levels that were fatal. [15] It would seem to be a miracle that Mr. McCloy survived.

As the mine rescue teams worked their way toward the second-left section they reported a red light slightly above the floor near 36-block four-belt. They were given permission to investigate the light at 2:10 a.m. It was a battery back up light for a carbon monoxide sensor. There was uncertainty about the effect on sensors inby this point if this unit was deenergized[16]. There was a further concern that the carbon monoxide system might respond to this unit being disconnected by turning on the battery of a unit that was in an explosive atmosphere, triggering a secondary explosion. This concern was heightened by the fact that the teams were now witnessing significant damage in this area. They knew that ventilation controls were likely missing inby their location.

It was decided to remove the teams to the surface while the carbon monoxide system was deenergized. The carbon monoxide system was deenergized at 3:57 a.m. Since the first bore hole was expected to breakthrough the roof of second-left within hour, it was decided to not allow the rescue teams to reenter the mineuntil after the borehole was through.

The drill rod broke through the roof of second-left only 200 feet from the barricade. The drilling team improvised a signaling system by using the drill rod as a sound source, hitting it on the surface with a hammer and placing their ears to it listening for return signals. From 5:42 a.m. to

[14] Page 33 starting on line 12 and page 34 starting on line 7 of the statement by Randal McCloy June 19, 2006 taken by MSHA – the 'valve' Mr. McCloy is referring to is the level on the SR-100 that activates the oxygen starter cylinder when a fabric tag is pulled as part of the donning procedure

[15] The carbooxyhemoglobin saturation levels for all the victims exceeded 64 percent with some as high as 78 percent these levels lead to diagnosis of anemic hypoxia as the cause of death.

5:52 a.m. silence was observed across the site to listen for any tapping on the drill bit that now extended into second-left --- there was no response. This was almost exactly 24 hours from the time that the second-left crew had started boarding their mantrip.

Samples of air from the new borehole indicated 1,280 ppm carbon monoxide, 20.3 percent oxygen, and 0.4 percent methane. The drill steels were withdrawn and a camera lowered. The drill team had hit perfectly in the entry inby the belt head. A camera was lowered through the hole and it was clearly visible that there was no damage in this area. There was no sign of any persons. Smoke was wafting past the camera in slow thin wisps.

It was decided to hold the second and third bore holes short to avoid having to remove the rescue teams again.

At 6:22 a.m., the mine rescue teams re-entered the mine. They took with them an experimental mine rescue robot. The robot was deployed near 32-block, four-belt but, developed technical problems because of the mud and water in the mine at 33-block, four-belt. This unit was not used again after 8:50 a.m. Carbon monoxide was measured here at 203 ppm with 20.6 percent oxygen and zero percent methane.

By noon the rescue teams had only made it as far as 44-block, four-belt. The extensive damage to the ventilation control stoppings was requiring that significant repairs be made in order to advance the fresh air base. These repairs slowed progress significantly. By this time teams had been changed several times.

At 2:15 p.m. a rescue team reached the first-left mantrip at 49-block, four-belt. They found nine dinner buckets. They disconnected the batteries on the mantrip. There was 44 ppm carbon monoxide and zero percent methane at this location. Readings taken on the entries of first-left showed 310 ppm and 335 ppm carbon monoxide in the belt entry and intake escapeway

[16] The concern was that taking this unit off its battery backup might activate the backup on a unit inby in an unknown atmosphere.

respectively with oxygen in the normal range and methane below 0.2 percent. Significant damage was reported in the area.

The rescue teams did a preliminary search of the entries on first-left. Since all of the first-left crew had been accounted for, it was determined to break with mine rescue protocol and only look for signs that the second-left crew may have taken refuge on that section. They found no signs that anyone had been in the section, and were directed to proceed toward second-left.

At 3:55 p.m., the teams were instructed to advance to 56-block, four-belt. The significant damage required considerable work, but the teams were nearing the second-left track switch and were working hard. They moved the 600 feet by 5:08 p.m. and requested permission to advance.

The first victim was found between 57- and 58-block, four-belt. Mr. Helms, the mine examiner, had been in the direct path of the blast less than 500 feet from the old-second-left section seals.

The principal means of communication to the surface was the mine pager phones. On the surface there were two pager phones in the mine office, one in the dispatcher's building, one just inside the mine portal and a new one installed near the OMHS&T mine rescue truck. In addition there were now over 100 people on the surface many of whom had cell phones. Although the site was being secured by the police, the national media had by now set up observation positions for their camera crews attempting to get images. What was not known at the time was some of these media crews also had directional listening devices pointed at the mine portal and were able to hear the pager phone. There was concern among mine management that if victims were found that the media would over hear and report such before there was time to individually talk with the families. Therefore, the mine rescue captains were asked to identify any victims as 'items' rather than use names when reporting to the command center. At 5:20 p.m. on January 3, 2006, the rescue team reported "…one item."

While disheartened by the discovery of Mr. Helms, the teams were even more anxious to move forward in the hope of finding the second-left crew. At 5:49 p.m. the forward most team was instructed to move to the seals of the old-second-left section. At 6:08 p.m., the team reported they had walked into the old-second-left section and that seal-10 appears to be gone.

After discussion among those in the command center, at 6:22 p.m. the instruction was given to advance across the seals toward the second-left section mouth. While the teams had been reporting significant damage, none of them had been prepared for the level of destruction they found. The seals were not simply blown apart as they had seen with the stoppings…they were gone. Nothing remained. Some reported seeing markings in the ribs and floor were the seals had been. Also, the first reports were making their way to the surface that the explosion had occurred inby the seals. Until then the assumption had been that the explosion originated in the second-left section. The teams were now at the second-left mains, 1,800 feet from the barricade.

At 7:00 p.m. the instruction was given to advance into second-left. The tangle of metal and debris that had blocked the second-left crew's escape slowed the progress of the rescue teams. By 7:25 p.m., they had only progressed 260 feet to the 6-block, six-belt crosscut. Air samples indicated 306 ppm carbon monoxide, 20.6 percent oxygen and 0.6 percent methane. The smoke was still swirling in the air, but the team reported seeing what appeared to be a mantrip several blocks ahead of them. Before advancing they were instructed to recheck the area between second-left and the point where they had found Mr. Helms to ensure they had not missed anyone. By 7:50 they had reached the mantrip located at 10-block, six-belt in second-left.

Excitement increased as they found footprints in the intake escapeway and followed them to the covers for 12 self-rescuers near 12-block, six-belt. It was 8:10 p.m. and the rescue team was only 1,300 feet from the barricade. By 9:34 p.m., the teams had advanced 400 feet to 16-block, six-belt with air readings of 362-ppm carbon monoxide, 20.7 percent oxygen, and 0.2 percent methane.
At 11:39 p.m. January 3, 2006 the first team reached the barricade. They entered to silence. It appeared that most of the victims were obviously deceased. As mine rescue members began to check for vital signs they heard what sounded like a moan from the inby, left side of the barricade … it was Mr. McCloy.

It had been over 40 hours since the explosion. The world was literally hanging on every message from the teams to the command center. The message that was ultimately recorded in their command center notes by the OMHS&T staff at 11:45 p.m. was "All are okay behind barricade – 12 men". This mistake was due to passing the message through several individuals. The MSHA command center notes record at 11:46 p.m. "12 people alive". The ICG command center notes recorded "All twelve at the face – barricaded at the face" At 12:18 p.m. another report came back that the "rescue team at face are bringing 12 people coming with them." The command center erupted in excitement, Harrison Tyrone Coleman, ICG's command center representative, related "I never saw so many old hairy guys cry in my life."[17] But it was not to last. A confirmation report came to the command center at 12:23 a.m. "11 items" and was confirmed at 12:30 a.m. as "11 fatalities and 1 survivor behind barricade". This miscommunication and the anguish its premature release caused are immeasurably regretted by all involved. This regret has been expressed many times.

While the communication issues were playing themselves out, the rescue team was evacuating Mr. McCloy. He was barely breathing, and had difficulty holding an SCSR breathing tube in his mouth. The rescuers used several SCSRs as they carried him to the fresh air base where they were able to put a positive pressure oxygen mask on him.

By 1:00 a.m. January 4, 2006 Randal McCloy was in an ambulance, on the way to the hospital. Mr. McCloy had been in the mine over 43 hours, most of which were high levels of carbon monoxide.

The process of recovering victims continued through the night and into the morning. The victims were transported from the mine in mantrips at 9:55 a.m. January 4, 2006 and left the site by ambulance.

Killed in the explosion and its aftermath were:

Martin Toler, Jr., Alva M. Bennett,

[17] Statement under oath by Harrison Tyrone Coleman February 21, 2006 starting on page 75

Fred Ware, Jr.,
Jesse L. Jones,
David W. Lewis,
Jerry L. Groves,
Thomas P. Anderson,
George J. Hamner,
James A. Bennett,
Marshall C. Winans,
Jackie L. Weaver,
Terry Helms

Those who survived the explosion, the initial response, and those that supported them on the surface while not suffering from physical injury are forever changed.

Surviving the January 2, 2006 day shift includes:

John Nelson Boni
William (Bill) Chisolm
Randal L. McCloy
Gary Rowan
Gary D. Carpenter
Roger Perry
Chris Tenney
Paul Avington
Joe Ryan
Alton Wamsley
Randy Helmrick
Eric Hess
Denver Anderson
Hoy Keith
John Patrick Boni
Ron Grall
James Fred Jamison
Jeffery Keith Toler
James Allen Schoonover
Denver Wilfong
Gary Marsh

At 10:00 a.m. on January 4, 2006 the last of mine rescue personnel were out of the mine.
The rescue phase was complete and the mine recovery/investigation began.

Photo 1

First-Left mantrip
Mantrip in buggy barn after it was transported to surface

Photo 2

Example of the debris at track overcast that would have prevented the crew from escaping in their mantrip

Photo 3

Second-left mantrip
Mantrip buggy barn after it was transported to surface

4 THE MINE RECOVERY

To allow for an investigation of the Sago Mine Disaster, ventilation in the mine had to be restored, the underground power repaired, the water pumped, and the mine examined to assure it was safe for people to enter. This activity was called the recovery of the mine.

The recovery of the mine presented several challenges. The initial focus was to develop ways to safely ventilate areas of the mine utilizing a Blowing System of ventilation.

A series of boreholes were drilled from the surface into areas of the mine to create a positive airflow through these areas. These boreholes functioned as the return side for areas that required ventilation. Some of the boreholes were used to allow atmospheric samples to be collected and analyzed. Other boreholes were used to dewater the area inby the destroyed seals.

To fully recover the mine, it was necessary to reestablish the electrical power system throughout the mine. This allowed for the dewatering of pooled areas of water and helped maintain the integrity of the return entries. The reestablished electrical system also permitted the use of the rail transport system to provide transportation for members of the recovery teams and for the transportation of supplies necessary to repair damaged ventilation controls.

To recover the mine, trained persons performed examinations of the mine, repaired damaged ventilation controls, and repaired or replaced damaged equipment. This was accomplished following plans developed by Anker West Virginia Mining Company and approved by the Mine Safety and Health Administration and the West Virginia Office of Miners' Health, Safety and Training.

4 THE MINE RECOVERY

4.1 Approved Recovery Plans

4.2 Record of Mine Recovery

4.1 Approved recovery plans

The "Recovery of the Mine" followed plans that were developed by officials of Anker West Virginia Mining Company (ICG) and approved by representatives of MSHA and WVMHS&T.

Approved plans are included in the ***Appendix 4.2***

Summary of submitted recovery plans:

* January 05, 2006 Submittal #1-R Approved 1/05/06
  Request to complete the drilling of borehole #2 on 1st. Left.

* January 06, 2006 Submittal #R-2 Approved 1/06/06
  Request to remove the power from the mine CO system.

* January 06, 2006 Submittal #R-3 Approved 1/06/06
  Request to complete the drilling of borehole #4.

* January 07, 2006 Submittal #R-4a Approved 1/07/06
  Request to drill a 24" borehole #5.

* January 08, 2006 Submittal #R-5 Approved 1/08/06
  Request to install 8" PVC pipe on top of hole #4.

* January 09, 2006 Submittal #R-5a Approved 1/09/06
  Request to change size of sampling tube.

* January 08, 2006 Submittal #R-6 Approved 1/09/06
  Request to drill borehole #5.

* January 09, 2006 Submittal #R-7 Approved 1/09/06
  Request to drill borehole #6.

* January 12, 2006 Submittal #R-7 Not Approved
  Recovery Plan Outline.

* January 12, 2006 Submittal #R-8 Approved 1/12/06
Recovery Plan Outline.

* January 12, 2006 Submittal #R-9 Approved 1/12/06
Request to re-drill and clean borehole #4.

* January 14, 2006 Submittal #R-10 Approved 1/14/06
Request to drill borehole #7.

* January 17, 2006 Submittal #R-10a Approved 1/17/06
Replaces request #R-10 changed to 16 inch hole #7.

* January 18, 2006 Submittal #R-11 Approved 1/18/06
Request to ventilate the #4 borehole with air line.

* January 19, 2006 Submittal #R-12 Approved 1/19/06
Request to use the #4 borehole for ventilation.

*	January 20, 2006	Submittal #R-7e	Phase 1	Approved 1/20/06
*	January 20, 2006	Submittal #R-7d	Phase 2	Approved 1/20/06
*	January 20, 2006	Submittal #R-7d	Phase 3	Approved 1/20/06
*	January 20, 2006	Submittal #R-7d	Phase 4	Approved 1/20/06
*	January 20, 2006	Submittal #R-7d	Phase 5	Approved 1/20/06
*	January 21, 2006	Submittal #R-7e-(1)	Amendment	Approved 1/21/06
*	January 22, 2006	Submittal #R-7d-(1)	Amendment	Approved 1/22/06
*	January 22, 2006	Submittal #R-7d-(2)	Amendment	Approved 1/22/06
*	January 22, 2006	Submittal #R-7e-(2)	Amendment	Approved 1/22/06

4.2 Record of mine recovery

The "Recovery of the Mine" utilizing mine recovery teams underground and representatives of Anker West Virginia Mining Company (ICG), MSHA and WVMHS&T at the Command Center began on the morning of January 21, 2006.

A record of the Command Center notes taken by representatives of WVMHS&T are included in **Appendix 4:** *Command Center Notes.*

5 THE INVESTIGATION

The purpose of this investigation was to carefully observe, inquire and examine systematically the events surrounding the January 2, 2006, Sago Mine Disaster. The WVOMHS&T investigation started on the morning of January 2, 2006, and certain aspects of it continue.

The WVOMHS&T joined representatives of MSHA, Anker West Virginia Mining Company, Inc. (ICG), the Sago Mine and the United Mine Workers of America so as to conduct an investigation that provided an opportunity to collect and share jointly information obtained during the investigation.

Mr. Doug Conaway (former Director), on January 9, 2006 formed the WVOMHS&T Investigation Team. This team consisted of: Mr. Conaway, Mr. Terry Farley, Mr. Brian Mills, Mr. Monte Hieb, Mr. John Collins, Mr. John Scott, Mr. John Hall, Mr. Jeff Bennett, Mr. Barry Fletcher and Mr. Robert True, Jr.

On January 10, 2006, the members of the WVOMHS&T team met with the MSHA Investigation Team at the MSHA District 3 Field Office in Bridgeport, WV. The MSHA Investigation Team members consisted of the following: Mr. Richard Gates, Mr. Richard Stoltz, Mr. John Urosek, Mr. Clete Stephan, Mr. Russell Dresch, Mr. Dennis Swentosky, Mr. Gary Harris, Mr. Joe O'Donnell, Mr. James Crawford, Mr. Robert Wilson and Mr. Tim Williams. Discussions at this meeting focused on joint participation during interviews, the recovery of the mine and on site investigations.

During the investigation additional representatives of WVOMHS&T were called upon to participate in the investigation. Those persons were Mr. Mike Rutledge, Mr. John Cruse, Mr. Bennie Comer, Mr. John Meadows, Mr. James Dean (acting Director), Mr. Randy Harris and Mr. David Stuart.

5 THE INVESTIGATION

5.1 Statistics and fact-finding

5.2 Evidence documentation

5.3 Omega seals

5.4 Flames and forces

5.5 What caused the explosion?

5.6 Self-contained self-rescuers (SCSR)

5.1 Statistics and Fact-finding

5.1-1 Enforcement Actions

The following enforcement actions have been taken as a result of the investigation.

Two (2) non-assessed control orders were issued in accordance with West Virginia Administrative Regulation Title 36, Series 19, Section 7.1 during the investigation.

On January 27, 2006 a notice of violation was issued that resulted in an order being issued to the operator for failure to allow United Mine Workers of America Representatives to accompany West Virginia Office of Miners' Health, Safety, and Training inspectors during the investigation. Case Number 002-0208-2006.
See **Appendix 5:** *Statistics and Fact-finding*.

Attached are copies of the violations issued by the electrical inspectors John Scott and Bennie Comer during this investigation. Case Numbers 129-0364-2006 and 023-0295-2006.
See **Appendix 5:** *Statistics and Fact-finding.*

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. TERRY M. HELMS

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 50

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 29 YEARS

EXPERIENCE AT THIS MINE 26 WEEKS

REGULAR OCCUPATION MINE EXAMINER/BELTMAN

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY , 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. MARTIN TOLER, JR.

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 51

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 32 YEARS

EXPERIENCE AT THIS MINE 14 WEEKS

REGULAR OCCUPATION SECTION FOREMAN

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY , 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. ALVA M. BENNETT

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 51

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 29 YEARS

EXPERIENCE AT THIS MINE 2 YEARS AND 26 WEEKS

REGULAR OCCUPATION CONTINUOUS MINING MACHINE OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. FRED G. WARE, Jr.

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 58

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 37 YEARS

EXPERIENCE AT THIS MINE 1 YEAR AND 26 WEEKS

REGULAR OCCUPATION CONTINUOUS MINING MACHINE OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. JESSE L. JONES

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 44

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 16 YEARS

EXPERIENCE AT THIS MINE 1 YEAR AND 36 WEEKS

REGULAR OCCUPATION ROOF BOLTING MACHINE OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY , 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. DAVID W. LEWIS

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 28

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 1 YEAR AND 32 WEEKS

EXPERIENCE AT THIS MINE 1 YEAR AND 32 WEEKS

REGULAR OCCUPATION ROOF BOLTING MACHINE OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. JERRY L. GROVES

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 55

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 28 YEARS

EXPERIENCE AT THIS MINE 1 YEAR

REGULAR OCCUPATION ROOF BOLTING MACHINE OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. THOMAS P. ANDERSON

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 39

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 10 YEARS

EXPERIENCE AT THIS MINE 16 WEEKS

REGULAR OCCUPATION SHUTTLE CAR OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2^{nd} Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. GEORGE J. HAMNER

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 54

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 26 YEARS

EXPERIENCE AT THIS MINE 1 YEAR 26 WEEKS

REGULAR OCCUPATION SHUTTLE CAR OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. JAMES A. BENNETT

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 61

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 25 YEARS

EXPERIENCE AT THIS MINE 20 WEEKS

REGULAR OCCUPATION SHUTTLE CAR OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY , 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. MARSHALL C. WINANS

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 50

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 23 YEARS

EXPERIENCE AT THIS MINE 1 YEAR 8 WEEKS

REGULAR OCCUPATION SCOOP OPERATOR

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY , 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's, Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

VICTIM INFORMATION
(Privacy Information Removed)

NAME OF VICTIM MR. JACKIE L. WEAVER

ADDRESS CONFIDENTIAL

DATE OF BIRTH CONFIDENTIAL AGE 50

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 26 YEARS

EXPERIENCE AT THIS MINE 2 YEARS

REGULAR OCCUPATION ELECTRICIAN

SPOUSE'S NAME CONFIDENTIAL

DEPENDENTS CONFIDENTIAL

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY, 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the medical report, death was caused by carbon monoxide poisoning.

5.1-2 Victim and Accident Information

ACCIDENT INFORMATION
(Privacy Information Removed)

NAME OF INJURIED Mr. RANDAL L. McCLOY

DATE OF BIRTH CONFIDENTIAL AGE 26

SOCIAL SECURITY NUMBER CONFIDENTIAL

EMPLOYED BY ANKER WEST VIRGINIA MINING COMPANY, INC.

MINE NAME SAGO MINE PERMIT # U-2016-98B

COAL MINER'S CERTIFICATION NUMBER CONFIDENTIAL

TOTAL MINING EXPERIENCE 4 YEARS AND 3 MONTHS

EXPERIENCE AT THIS MINE 1 YEAR AND 4 MONTHS

REGULAR OCCUPATION ROOF BOLTING MACHINE OPERATOR

INFORMATION CONTACT PERSON CONFIDENTIAL

DATE OF ACCIDENT 2nd DAY OF JANUARY , 2006

DESCRIPTION OF ACCIDENT:

On January 2, 2006 at approximately 6:30 A.M. a methane and/or coal dust explosion occurred behind the 2 North East Mains seals of the Anker West Virginia Mining Company's Sago Mine causing a mine disaster. The explosion resulted in the immediate death of (1) one miner and blocking the escape route of twelve other miners, causing the death of eleven of these miners. The explosion destroyed the North East Mains Seals, the stopping line and overcasts that provided intake air to the seals, the intake stopping line that provided intake air to the 2nd Left working section, several intake and return stoppings along the 4 track and an overcast at 12 block of 4 track, creating a short circuit of ventilation. According to the accident report submitted by the operator, Mr. McCloy's injuries were caused by carbon monoxide poisoning.

5.1-3 Interviews

An important part of this investigation, obtaining information through interviews, was a coordinated effort between MSHA and WVMHS&T.

Representatives of MSHA and WVMHS&T participated in the questioning of persons interviewed. *A list of these representatives can be found in* **Appendix 5:** *Statistics and Fact-finding.*

As in any interview process, the information obtained usually helps to answer questions directly or provides information as to where other answers may be obtained.

Several people participated in interviews. Included in those interviewed were miners underground at the time of the accident, mine management persons who entered the mine during the initial rescue attempt, persons who were involved in the seal construction, mine rescue team members, representatives of mine management (Anker and ICG), representatives of MSHA, representatives of WVOMHS&T, medical field persons, and consultants. *A list of persons and date of interviews can be found in* **Appendix 5:** *Statistics and Fact-finding.*

Transcripts of interviews can be found at *www.wvminesafety.org*.

5.2 Evidence Documentation

5.2-1 Mapping of Evidence

5.2-2 Collection of Evidence

5.2-1 Mapping of Evidence

As soon as mine recovery efforts permitted general re-entry into the mine a coordinated mapping effort was conducted in order to document in detail the location and description of all relevant evidence. This involved ten (10) different mapping teams comprised of personnel from MSHA, OMHS&T, employees and consultants of International Coal Group (ICG), United Mine Workers of America (UMWA), and on occasion other guest representatives who either assisted or observed.

The following is a list of the organized mapping teams:

GENERAL MAPPING -- SIX (6) teams

EVIDENCE MAPPING AT THE BARRICADE – ONE (1) team

FLAMES AND FORCES -- ONE (1) team

ELECTRICAL MAPPING – TWO (2) teams

The mapping effort began on January 27, 2006.   Maps were compiled on a variety of scales ranging from 1" = 10' up to 1" = 100'. Mapping proceeded generally on a 7-day schedule, although a day break in the schedule was taken now and again. The effort was largely conceived and organized by personnel within MSHA Tech Support. Assisting in this effort to a significant degree were ICG personnel and representatives, including representatives of Alpha Engineering who provided consulting services to ICG and produced a final composite version of all work maps compiled. These were proofed for completeness and accuracy by MSHA Tech Support and are included in **Appendix 5.2.**

Evidence of post-explosion debris such as pieces of Omega blocks, toppled overcasts, pieces of ventilation curtain, equipment, wire mesh roof mesh, etc. were carefully described and their positions measured relative to known reference points and were located on the work maps. At the end of each mapping day the work maps from each team were turned in and reproduced for the principle parties involved in the mapping effort (see **Section 5.3-2**).

The Flames and Forces mapping teams recorded damage magnitudes, directions, and bending sequences to roof pans and plates, wire roof mesh, and belt hangers. Notes were made as to the direction of propagation of explosion forces as interpreted by this evidence. A summary map of some of this information compiled by OMHS&T is contained in **Appendix 5.4-1:** *Flames and Forces Map.* Engineering tests conducted on samples of these metal structures were performed through MSHA and contributed to this effort.

At the request of OMHS&T mapping also included supplemental surveying of the mine roof and floor in the areas inby the Old 2nd Left seals. This work was performed by Alpha Engineering, consultants for ICG. The elevation control points provided have been compiled into a set of contour maps by OMHS&T and are included in **Appendix 5.4-1**: *Floor Contour Map/ Roof Contour Map*.

Surface mapping of gas lines and wells, utility lines, and lightning-related documentation was performed by OMHS&T with the cooperation of ICG and others, including representatives of the gas producers in the area who donated valuable time and information to the effort. General informational maps of various topographic and aerial photography formats showing the relationship of surface features to underground features were also prepared and have been contributed in various paper and electronic formats to assist in the investigation.

Maps of electrical systems and resistivity surveys were also prepared and are addressed in **Section 5.5**.

5.2-2 Collection of Evidence

An important phase of the investigation centered on the collection of physical evidence. MSHA was the primary collector, documentor, and custodian of evidence obtained during the investigation.

- Mr. Gary Harris of MSHA was in charge of the evidence collected.
- Mr. Robert L. True, Jr. assisted and represented the WVOMHS&T.
- Other representatives of Anker West Virginia Mining Company, Inc. (ICG), Sago Mine and the UMWA also assisted in the collection of evidence.

The physical evidence collected was documented and verified through chain of custody records kept by MSHA. The WVOMHS&T, as part of the investigation, requested and obtained a dewatering pump with its power cable and other components that were found in the previously sealed area. This pump and components are currently in our custody.

Mr. Michael Rutledge served as the person responsible for the photography for WVOMHS&T. Mr. Rutledge and his assistants produced several photographs as part of the investigation.

5.3 Omega Seals

5.3-1 Approvals and Construction

5.3-2 Post-explosion Examination

5.3-1 Approvals and Construction Summary

Chapter 22A-2-5 (effective 7/1/71) of The West Virginia Code and Title 36 Series 17 (effective 3/1/82) of the Administrative Rules and Regulations are a reference for the requirement of Unused and Abandoned Parts of Mines.
These are included in the **Appendix 5.3.**

Anker West Virginia Mining Company (ICG) representatives abandoned the area of the Sago Mine referred to as North East Mains or Old 2nd Left Section. Initially this abandoned area was ventilated by the mine's ventilation system. Later a decision was made to seal this area.

On October 12, 2005, Anker West Virginia Mining Company submitted to the WVMHS&T Region One (received 10/13/05) a request to add an Omega Concrete Block Seal Method and Plans to the approved ventilation plan. The Region One office reviewed and approved this request on October 14, 2005.
This request and approval are listed in the **Appendix 5.3.**

On October 12, 2005, Anker West Virginia Mining Company submitted to the WVMHS&T Region One office (received 10/18/05) a request for a Seal Plan for 2nd. Left Mains and a two step plan for ventilation of this area. The Region One office reviewed and approved this request on October 18, 2005.
This request and approval are listed in the **Appendix 5.3.**

According to testimony of persons interviewed, the ventilation controls installed and the seal construction were performed by employees of Anker West Virginia Mining Company and employees of Garrett Mine Service, an Independent Contractor.
See transcripts of persons interviewed at: www.wvminesafety.org.

On December 9, 2005, prior to completion of the seals and Step 2 of the approved plan, Mr. John Collins, District Mine Inspector, WVMHS&T, conducted an inspection of the seals. *See a copy of the inspection report in the* **Appendix 5.3**

According to testimony of persons interviewed the Seal Plan and Step 2 of the approved plan were completed on December 11, 2005. *See transcripts of persons interviewed at: www.wvminesafety.org.*

5.3-2 Omega Seals: Post-explosion Examination

Ten (10) Omega block seals were installed to isolate the Old 2nd Left Section from the remaining active Sago Mine (**Figure 1**). Constructed of Omega 384 Blocks and a high-strength (2,000 PSI) Bloc Bond mortar, these seals are considered an alternative seal to the standard Mitchell/Barrett seal[1]. This seal design creates a forty inch (40") thick barrier between the abandoned area of the mine and the active area of the mine. This seal has been designed, tested, and approved to be installed without hitching into the roof, floor or ribs and construction utilized this no-hitching proviso. The actual design specifications are detailed in the approved plan (see **Section 5.3-1**). Mine seals should conform to the following guidelines:

(1) The seal is constructed of flame-resistant materials or be sufficiently coated with flame resistant materials.

(2) The entry with the lowest elevation must be equipped with a water trap to prevent impounding of water.

(3) The entry with the highest elevation must be equipped with a tube to permit the monitoring of mine gases as they build up behind the seal.

(4) Except for the gas sampling tube, no other continuous metal structures pass through the seal structure, either internally or around the seal perimeter.

(5) The materials and design must be able to withstand a minimum of 20 psi static pressure in the event of an explosion, as prescribed by MSHA.

Seals construction was completed on December 11, 2005. On January 2, 2006 a methane explosion occurred from within the sealed area which resulted in the destruction of all ten (10)

[1] Mitchell/ Barrett seals are typically built of 8"x 8"x16" solid concrete blocks that are cross-linked, fully mortared, and contain a center pilaster.

seals. On January 27, 2006 investigation teams entered the mine to map and gather evidence to assist in determining the cause, intensity, and point of origin of the explosion.

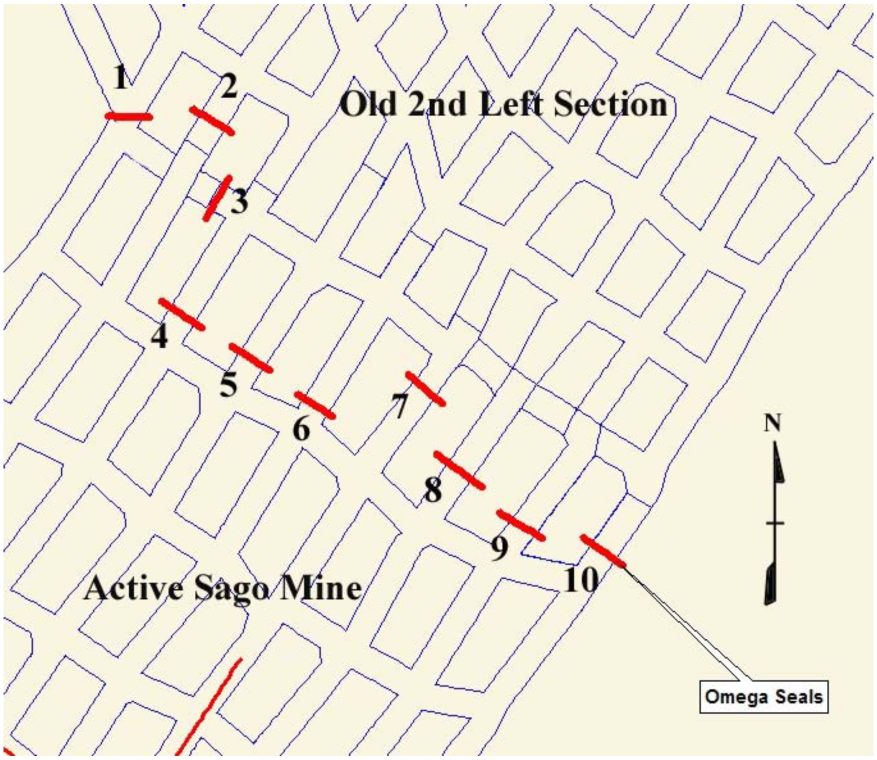

Figure 1: Location of Omega seals in the Sago mine.

All ten (10) Omega Block seals were totally destroyed in the explosion. Remnant pieces of Omega blocks ranged in size from baseball-sized pieces to sand-sized. The majority of the debris appeared golf ball-size or smaller [2].

Mapping of the seal remnants and debris was performed in order to document the manner and the extent of damage. The force of the explosion completely removed and pulverized the seals to the point that mapping teams could determined the location of the seals only by locating the concrete and mortar attached to the roof, ribs or floor. Only three (3) seals had Omega blocks still remaining at their installed seal locations (seals #1, #2 and #9). The debris from the seals was distributed in an outby direction from their installed location over a distance of several hundred feet. This, together with other evidence, led to a determination that the explosion forces originated from inside the sealed area (see **Figure 2**).

[2] The exception was Seal #1 which had a large number of pieces that were ¼-size or larger.

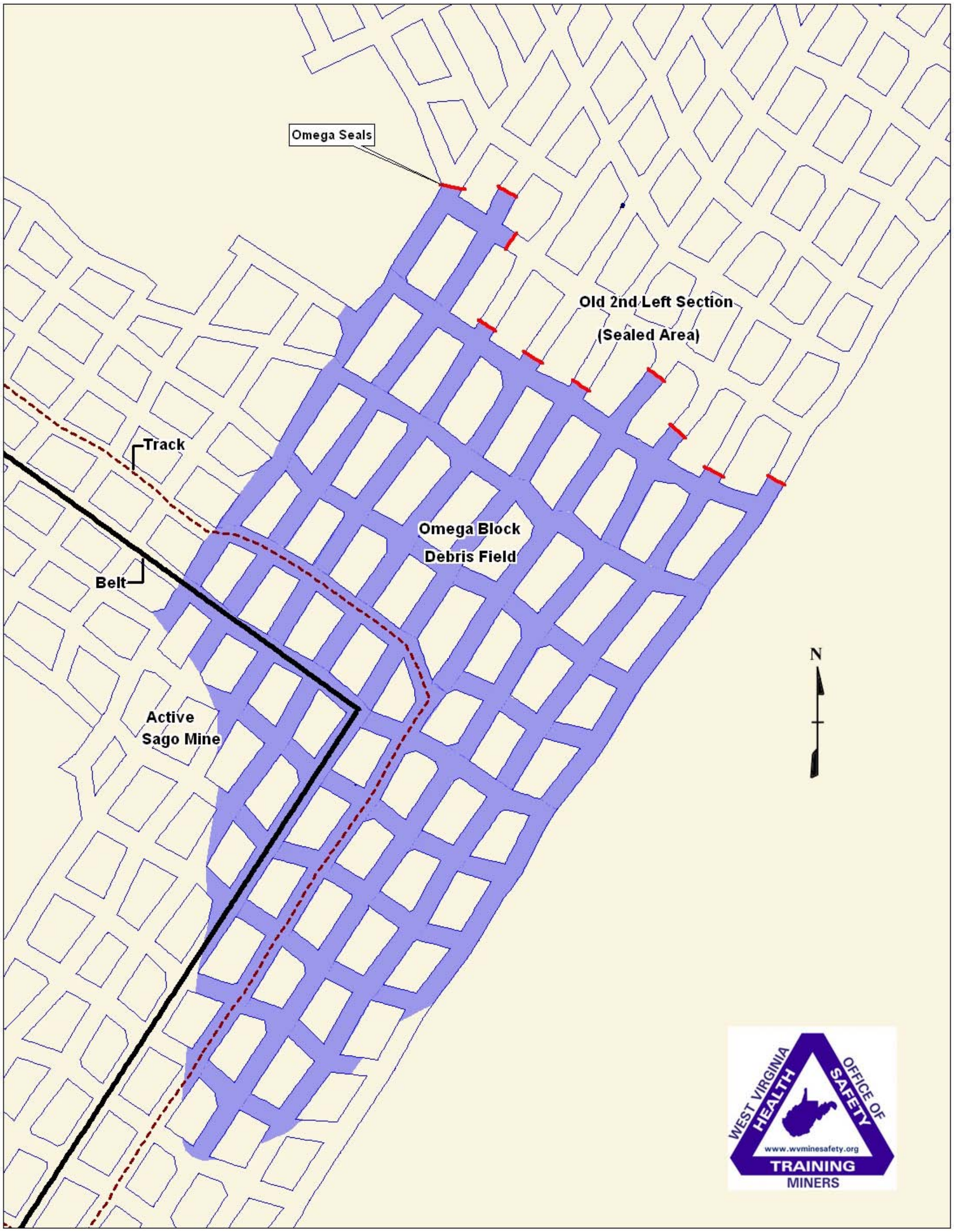

Figure 2: This illustration shows the approximate distance and symmetry of the debris field created by the ten (10) destroyed Omega seals.

Photo 1: Omega Debris - In First Outby Crosscut Between Seal #1 & #2 (Courtesy of MSHA)

Prior to installation of the #6, #7 and #8 seals, an 8-guage, 4"wire roof mesh was installed against the roof as supplemental roof protection. As is the required practice, this mesh was found to have been cut away prior to seal construction as a precaution to preclude the possibility of allowing stray electricity to enter the sealed area. The lengths of the removed sections allowed for a minimum of one (1) foot of gap from the seal surface to the remaining wire mesh.

Two water traps in #1 seal were constructed of non-metallic pipe. No confirmed components of the water trap were discovered during the investigation. The gas monitoring sample pipe in #10 seal was steel pipe, as prescribed in the approved plan. Except for the required sample tube, no other metallic structures were found which may have crossed the seal barrier.

As a matter of sound practice, seals are installed at a location where the ribs, roof, and floor are competent and stable. This criteria was complied with, in regards to all ten (10) Omega seals. However, it is worth mentioning that the #10 seal had some mild cutter roof problems on the outside rib, which could have been a possible source of some of the methane gas that had been detected on occasions outby the seals. In addition, the #1 seal was installed diagonally across the entry, which is not a typical installation. Evaluation of the rib surfaces after the explosion, however, did not indicate that anchorage at the rib was an issue in seal failure.

Members of the work crews involved in construction of these seals were interviewed and their testimony evaluated in conjunction with the mapped evidence. Several aspects of possible variations to the approved seal designs were identified and their potential role in performance reduction of the seals was given scrutiny during the investigation. Variations from the approved plan were found to include:

(1) some application of dry mortar mix to the prepared mine floor prior to seal installation,

(2) the application of at least some of the mortar in vertical internal joints was indirectly applied by working it into seams between blocks rather than directly to individual block faces,

(3) the wedging of two instead of three header boards at the top of the seal and the sideways rather than end-facing installation of wedges between the header board and mine roof,

(4) the average width of seal #1 was 21.2 feet, and

(5) the average width of seal #2 was 20.36 feet.

In June – 2006 foundation coring of all ten (10) seal locations was performed, under the direction of MSHA. The floor of a mine is not necessarily level and smooth. Dry mortar was used in places to establish a level and smooth foundation to initiate seal construction. The thickness of the mortar foundations varied from no mortar on the mine floor to approximately 2 ¾ inches of mortar. The mathematical average of all samples was 1 inch. Conditions of the samples taken ranged from dry powder to semi-cured mortar (see **Appendix 5.3**: *Seal Foundation Boring Test*).

The method of mortar application of the vertical joints varied. In some cases it was troweled on, in others it appears it was applied from the horizontal by mixing the mortar to a soupy texture and forcing it between the joint faces. The outer facing appears to be consistently applied, and in accordance with the approved plan.

The anchoring of the seal to the mine roof is done by wedging three rows of header boards between the roof and top row of Omega blocks (along the length of the seal). Between each row of wedged boards, mortar is placed in the voids. This anchoring is difficult at best, involving driving wedges that are over one's head securely with a sledge hammer. Interviews indicate this was the most difficult phase of the seal construction. Interviews of the workers who constructed the seals indicate that the header boards were placed full length, across the entry and wedged, with spacing of the wedges around 12 inches and on occasions up to 18 inches. The boards closest to the outer edges of the seal were wedged continuously along the boards. Installing the middle board was often a most difficult task.

Investigative findings of the seal materials and construction practices that were used in the Old 2^{nd} Left seals were used to build and test seals of equivalent construction at NIOSH's Lake Lynn Experimental Mine during the period April 15, 2006 to October 19, 2006. These tests were designed to

(1) determine if the construction practice employed at the Sago Mine met or exceeded the 20 PSI static pressure criteria, and

(2) replicate the actual forces of the explosion that were exhibited at the Sago Mine.

This testing is still under review and final results have not been officially released. Preliminary findings indicate that the seal construction methods and materials used to construct the Old 2^{nd} Left seals were capable of producing a seal that could withstand an explosion in excess of 20 PSI, static pressure.

The following are a series of photographs illustrating the remains of the seals at Sago after the explosion. These photographs were taken by MSHA photographers and the photos are courtesy of MSHA.

Photo 2. Location: Seal #1 (Courtesy of MSHA)

Photo 3. Location: Seal #2 (Courtesy of MSHA)

Photo 4. Location: Seal #3 (Courtesy of MSHA)

Photo 5. Location: Seal #4 (Courtesy of MSHA)

Photo 6. Location: Seal #5 (Courtesy of MSHA)

Photo 7. Location: Seal #6 (Courtesy of MSHA)

Photo 8. Location: Seal #7 (Courtesy of MSHA)

Photo 9. Location: Seal #8 (Courtesy of MSHA)

Photo 10. Location: Seal #9 (Courtesy of MSHA)

Photo 11. Location: Seal #10 (Courtesy of MSHA)

5.4 FLAMES and FORCES

5.4-1 Mapping of Explosion Forces

A discussion on the methods used to map the explosion forces is presented here because this was an important part of the determining of the origin of the explosion, the sequence of blast forces, and the relative magnitudes of these forces. This section describes the effort to map the explosion behind the Omega seals, which began January 27, 2006. By this time vertical boreholes had been drilled near the lowest elevation of the mine at the back of Old 2nd Left in order to re-establish ventilation, and regulators had been installed to control access and airflow.

It took some time to become acclimated to the conditions behind the seals and to become familiar with the patterns of damage produced by the explosion. The area was dark with soot, survey spads[1] were difficult to find (or no longer existed), and a strong creosote smell existed from the effects of coking. Mapping efforts began with an inspection of the top end of Old 2nd Left Section in #2 entry near the edge of the water pool that had been pumped down to keep the newly-drilled ventilation boreholes open. This area of Old 2nd Left is the lowest in elevation. It is also the wettest, due to a sandstone paleochannel[2] that has eroded the immediate shale roof and the now lies unconformably atop the coal seam in this area. Water flows from this sandstone are heavy enough that a deep well turbine pump must be kept running to keep the water level constant. On January 27th the water level was approximately eight (8) feet lower than it was at the time of the explosion. At the new shoreline, methane was bubbling out of the mine floor, registering 0.3% on a ITX gas detector.

A line of stoppings between the #2 and the #3 entries had been used before sealing to provide ventilation to the section. The first three (3) stoppings going up into Old 2nd Left Section had toppled over, but the remnants were in fairly large pieces. The remainder of this line of

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1 Survey stations used underground for determining ones location on a map.

2 A body of sandstone that is an ancient stream channel formed shortly after the immediate shale roof was deposited.

stoppings going from this point up to the waters edge looked as if they had been pulverized – all except for the last two stoppings which we would later learn were partially submerged at the time of the explosion[3]. Later, as water levels dropped further, the stoppings and line curtains which had been totally under water at the time of the explosion were found to be largely intact, although some not completely so.

Photo 1 shows the remains of the second stopping outby from the waters edge knocked down in a southwesterly direction but with the individual 6" hollow-core cinder blocks substantially intact. The wire roof mesh was bent back in the same southwesterly direction and provided corroborating evidence from two or more features to show the dominant direction of the forces of the explosion at this location. Had the stopping not been at least partially submerged, it too would likely have been pulverized.

Photo 1. About 15' outby spad 3716 (STA-2) in #2 entry. Stopping of 6" cinder block, down. Wire roof mesh partially down.

Step by step, cross-cut by cross-cut, entry by entry, clues about the forces of the explosion were observed and recorded. In this manner, the direction of the explosion pressure waves were

[3] Structures submerged in water were afforded protection from the explosion.

mapped. The summary map of this effort by OMHS&T is contained in the *Flames and Forces Map* in **Appendix 5.4-1**, and additional information compiled by the joint mapping teams can be found in **Appendix 5.2.**

5.4-1a Bending of roof pans and plates

Before the end of the first day of mapping a general pattern had begun to emerge about the pattern of preferential bending that had taken place on many of the pans and plates that were bolted to the mine roof. **Square roof pans** (more commonly known as "spider plates") and **round roof pans** (also known as "pizza pans") are supplemental passive support plates that are made from galvanized sheet metal. They were installed on approximately 4-foot centers using roof bolts, and each utilized a roof-bolt plate as the bearing surface for the **roof bolt head.** Additional **wire roof mesh** was frequently installed between the roof pans and the mine roof to supplement the passive roof support. These structures are illustrated in **Photo 2**, below.

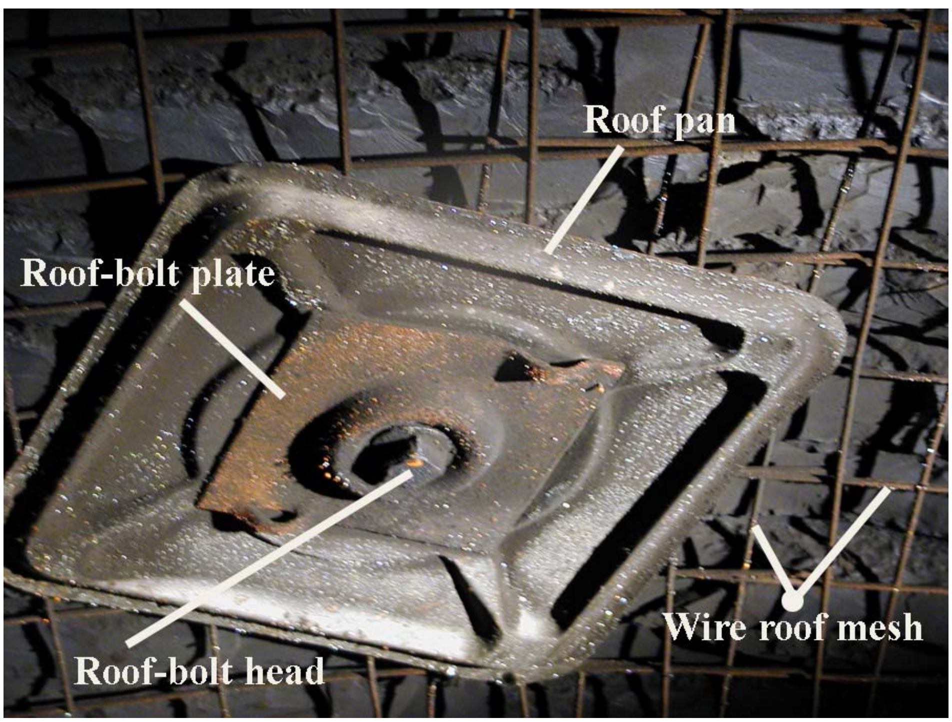


Photo 2. A typical arrangement of roof support, consisting of a roof bolt, roof bolt plate, roof pan, and wire roof mesh—all held against the mine roof by the head of the roof bolt. Square pans (commonly called "spider plates") and round pans (commonly called "pizza pans") are not used everywhere in the sealed area. Nor was the wire roof mesh used everywhere. Where it was used, the blast forces of the explosion altered their configuration in a way that helped us to reconstruct details of the blast.

The morphology of the bending of the roof pans, roof plates, wire roof mesh, and in some cases the roof bolts themselves, as a result of the explosion, provided a wealth of information about the forces that had interacted with them. The direction and the relative magnitude of the forces were determined by the degree of deformation of these materials.

The *Flames and Forces Map* in **Appendix 5.4-1** uses black, red, and blue arrows to indicate the direction of blast forces. Often, the bending was in two or more directions, and in many of those cases the order in which the bending occurred could be determined by the sequence and geometry of bend overlaps.

Flames and Forces Map (see **Appendix 5.4-1**):

1) **Red** arrows: Direction of *initial* forces, when two force directions were indicated and the relative timing could be distinguished from the bending.

2) **Blue** arrows: Direction of *secondary* forces, when two force directions were indicated and the relative timing could be distinguished from the bending..

3) **Black** arrows: One direction of bending. Whether from the initial forces or the secondary forces, could not be proven.

A brief discussion of our interpretation is given below to describe how the origin of the explosion and the relative magnitudes of the forces were inferred. It should be mentioned here that other maps with somewhat different interpretations but equal validity have been produced by other teams; perhaps using slightly different criteria. The absence of an arrow placement on the OMHS&T map does not indicate that the forces were absent; rather just that corroborating evidence to indicate a clear bending direction or sequence of bending was not present at that particular location. When in doubt, the depictions of force directions were omitted. Severe, omni-directional damage to roof pans and plates is indicated by red-shading of those areas on the *Flames and Forces Map* and also in **Map 1.**

Unidirectional bending

The simplest bending morphology of roof pans was one fold in one direction, and this consisted of either corner bending or edge bending, at angles ranging from 45 degrees to 180 degrees from the horizontal[4]. When the majority of bent pans at a particular location were generally in the same direction, this was indicated on the *Flames and Forces Map* by a **black arrow**.

Photo 3. Simple plate bending of a roof pan in one direction. When neighboring pans also showed bending in the same direction this was plotted on the Flames and Forces Map as a single black arrow.

Multiple-direction bending

The roof pans were often bent in multiple directions. Where the pan was bent in two directions the sequence of forces could often be determined by observing the pattern of folds. **Photo 4** shows an example where one end of the square roof pan is folded over the other end. In this case, the first force came from the right and the second forces came from the left. When the preponderance of evidence at a particular location was consistent with this interpretation the sequence of multiple pressure waves could be determined. The *Flames and Forces Map* shows the first-bending with a **red arrow** and the second-bending with a **blue arrow**.

[4] Bending at lesser angles was present, but not a good indicator of force direction.

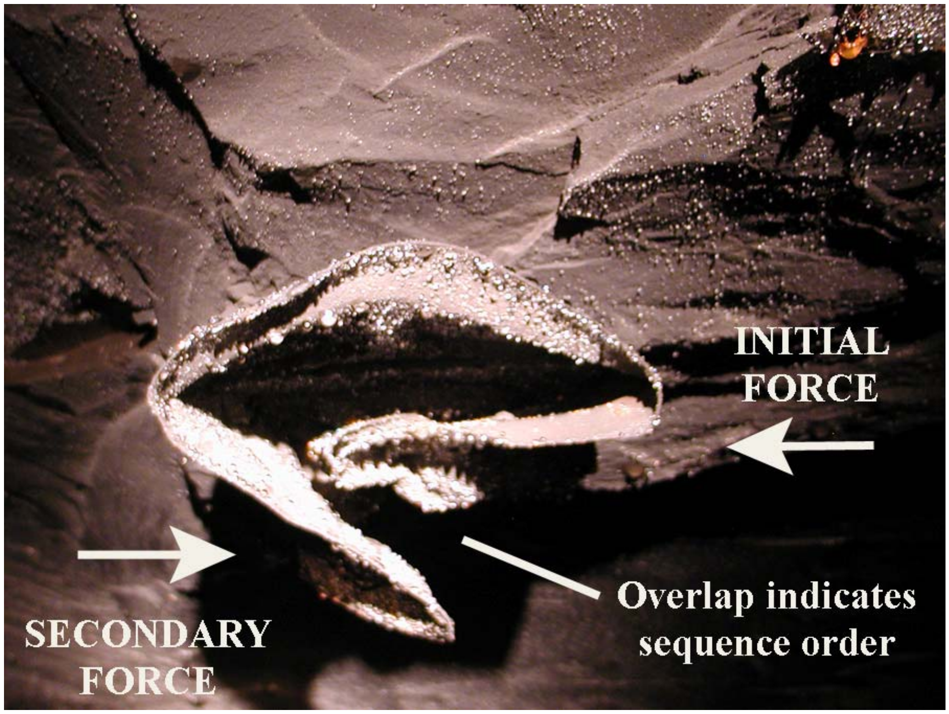


Photo 4. The relative order of initial and secondary pressure waves was interpreted in this example to be from the right, then the left, respectively, based on the overlapping sequence of the pan ends.

A variation of this interpretation of bending morphology is shown in **Photo 5**. Here, there is one direction of bending at first glance but on the side-opposite the bent left edge of the pan the corner of the bolt plate is bent to nearly 90° -- with a hole punched into the roof pan with the same shape and location as the bolt plate—which showed that it had been originally bent together with the bolt plate from the opposite direction (right to left). A secondary wave subsequently straightened the pan back to being flush with the mine roof (forces acting left to right) but left the bent edge of the bolt plate at its original 90° deflection. This type of pan bending morphology was fairly common. Evidently, a primary pressure wave from the right was followed by a secondary pressure wave from the left.

Photo 5 also indicates another complicating factor in that reflections from nearby solid vertical surfaces (such as a solid coal rib or a ledge of uneven roof) can produce localized variations in the bending. In this case the bent edge not identified by an arrow is the edge closest to the coal rib. This bend is likely an effect of local reflections off the coal rib.

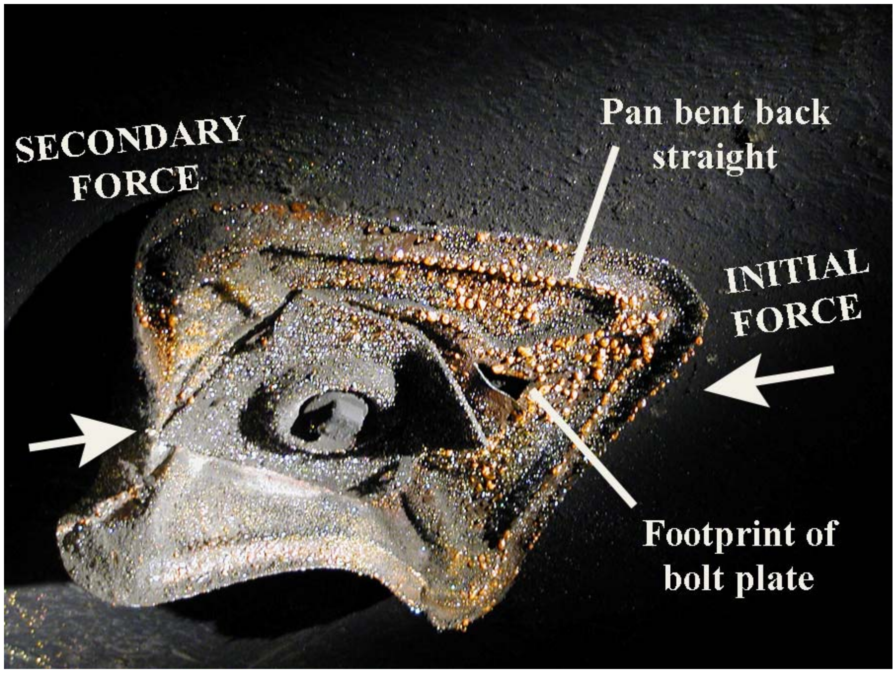


Photo 5. Initial forces bent the right side of this pan and bolt plate, leaving a footprint in the pan where the edge of the bolt plate punched through. This was followed by a secondary set of forces coming from the opposite direction which pushed the bolt plate back flush to the roof but leaving the corner of the bolt plate as originally bent.

Photo 6. An example of a severely deformed roof pan (“spider plate) that was found in the #9 entry just inby Seal #10. This is typical of the degree of bending and damage found between the seals and just after the first line of crosscuts inby the seals. This type of damage was also found in other areas of the mine where there were significant obstructions and where there was first-mining only (no “bottom-mining” done on retreat).

There were many variations in the bent-pan morphology due to local turbulence that complicated the inference on the blast forces. Pans that were located near entry/cross-cut intersections frequently had conflicting indications of the force direction. In order for a particular force direction to be accepted as an indication of a pattern, it was necessary to corroborate the directions of pan bending in a given area and not use just one or two pans. The best data were obtained where the mine roof was fairly even in areas that were mid-way between entry/cross-cut intersections.

<u>Severe, omni-directional deformation of roof pans</u>

A special category of pan deformation included roof pans that were severely deformed in all directions around the bolt-head[5]. This type of plate bending was found in areas where turbulence and physical barriers to the propagation of the blast forces existed, such as gob piles, dead-heads against solid coal ribs, etc. An example of this is shown in **Photo 6**.

Examples of this type of damage generally were found in those areas that were:

1) **not submerged below water** level at the time of the explosion, and

2) were **first-mined, only** (mine roof heights of typically 6-8 ft.).

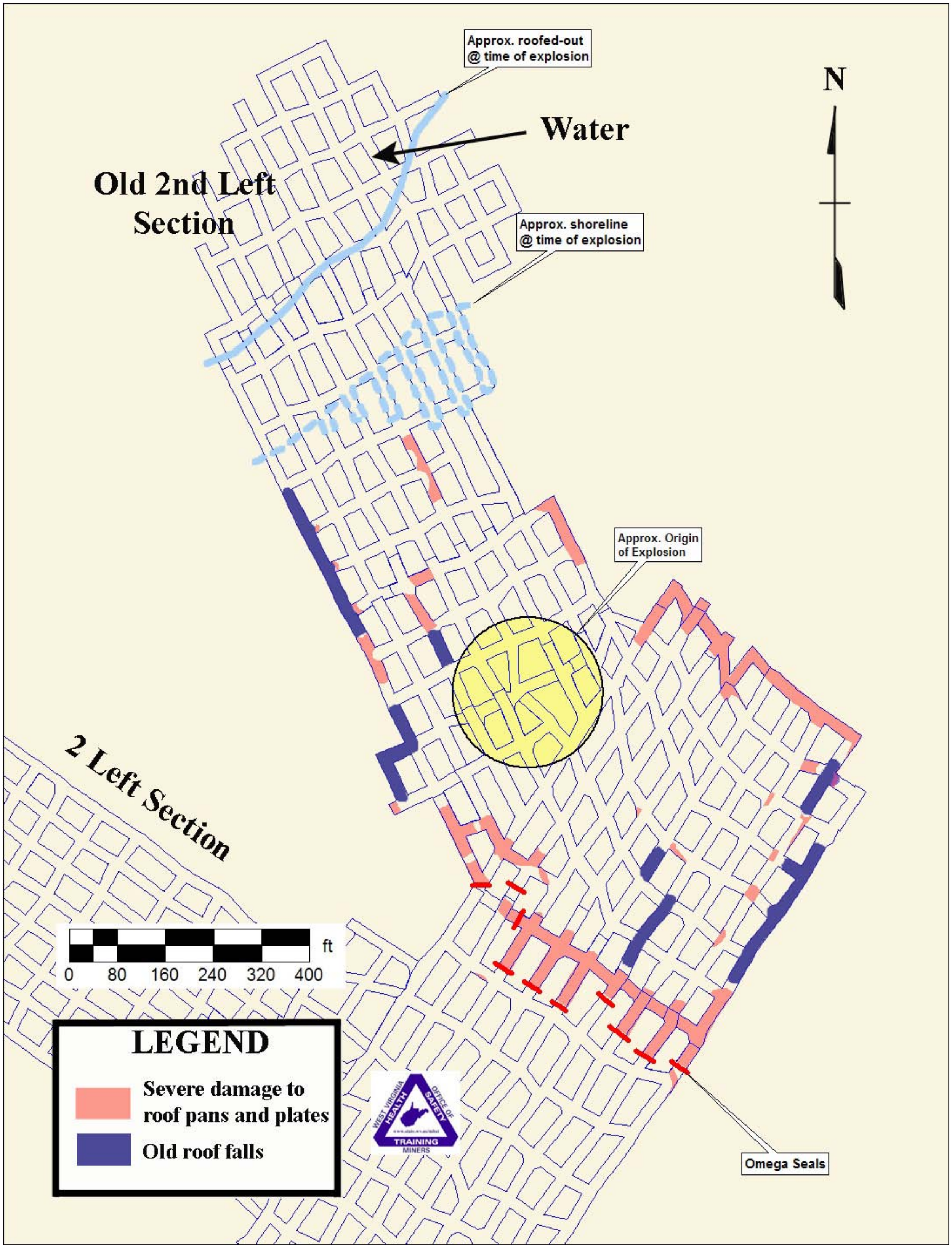
Further, this severe pan/plate bending was prevalent in a given area only if one or more of the following conditions were also present:

1) entry obstructions in the floor such as gob piles which reduced the entry height or opening approximately thirty percent (30%) or more;

2) ragged roof due to bad top; and

3) dead-end headings, reflections around roof falls, 90-degree elbow turns, solid coal face along the outside perimeter of the mine workings, and between the seals to the first line of crosscuts inby the seals.

5 Bolt plate was often similarly bent



MAP 1. Areas where pan and plate deformation was severe were noted during the course of the mapping effort. These areas were all above the water pool, mostly where bottom-mining had not occurred, and where obstructions impeded blast propagation such as along the solid coal perimeter, next to existing (old) roof falls, and also at the seals themselves.

It should be noted that there were many examples of pans and plates that showed less damage interspersed with these examples of high damage. Clearly, local turbulence played an important role in the type and severity of pan/plate deformation.

5.4-1b Bending belt hangers

Belt hangers were also used as indicators of the direction/magnitude of the blast in several instances. The belt entry was mapped both in front of and behind the Old 2nd Left seal locations for the purpose of documenting the direction and degree of bending of the belt hanger flanges.

Photo 7. An example of a bent belt hanger, which were usually bolted directly to the mine roof with no pan underneath. Their purpose is to provide an anchor point to hook chains to suspend the conveyor belt structure. This is a smaller version of the 4"x 4" belt hanger flanges that were typically used throughout the mine. Originally the angle of the flange was 90° (+ / - 1 degree). This bending was studied as another source of information to interpret blast force direction and magnitude.

Two (2) mapping surveys of these structures were performed. The first survey was performed on February 16, 2006 by two personnel with the OMHS&T and the second was performed over a seven (7) day period from April 5 to April 11, 2006 by a joint team comprised of personnel from Alpha Engineering, ICG, and OMHS&T.

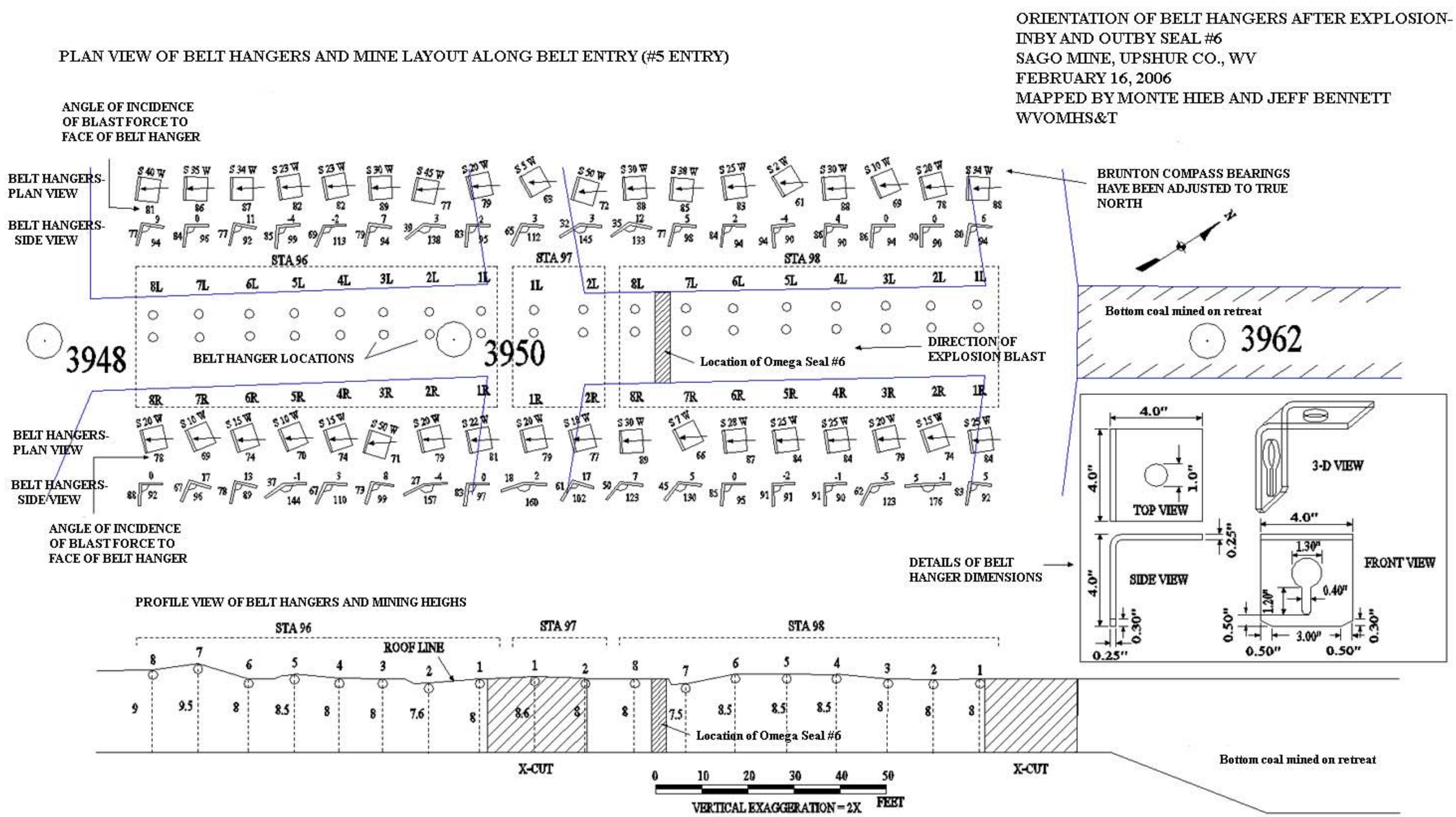


Figure 1. Results of Belt Hanger Survey 1 performed on February 16, 2006. Location is in the #5 entry (former belt entry) in the vicinity of Omega Seal #6. See **Appendix 5.4** for more detail.

Belt Hanger Survey 1

This first effort at mapping the belt hangers started with 36 belt hangers in the #5 belt entry in the vicinity of the Omega seal #6 location—14 of which were located behind Omega Seal #6 and 22 on the front (outby) side (see **Figure 1**).

A larger version of this map is provided in **Appendix 5.4-1**: *Belt Hanger Survey 1*.

Uncertainty exists as to exactly how the hangers came to be bent, although it has been postulated that hangers bent at the "keyhole" such as shown in **Photo 7** were likely impacted by flying debris. Hangers that were uniformly bent (as most were) likely were bent by air blast pressures[6]. Some of the hangers could have been bent in the course of normal mining operations or during the recovery of the belt structure after mining.

The significance of this information is discussed in **Section 5.4-2**.

Belt Hanger Survey 2

The second effort at mapping the effects of the blast on belt hangers was more ambitious and covered the majority of the remaining lengths of belt entry in the area inby the seals. In conjunction with the prior work that examined the bending of roof pans and plates, this information has provided both the sequence and magnitude of the explosion forces. Maps summarizing graphically the results of both Belt Hanger Survey 1 and 2 can be found in **Appendix 5.4-1:** ***(****Belt Hanger- Maps 1-7)* of this report.

[6] Testimony by Dr. Steve Sawyer

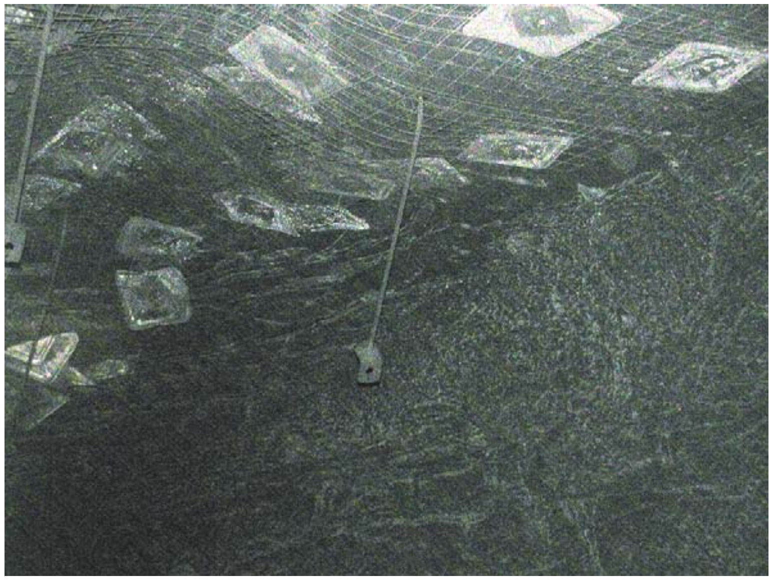


Photo 8. Occasionally, belt hangers were suspended from roof bolts when the height of the mine roof was excessive. In this case, either the last pressure wave or the most forceful pressure wave left these structures bent as shown.

5.4-1c Damage to wire roof mesh

As mentioned previously the wire roof mesh was also used as an indicator of the direction of explosion forces. Often a sense of the primary blast direction could be discerned from the deformation it sustained. An example of this is shown in **Photo 9**.

Photo 9. Wire roof mesh used as an indicator to establish apparent direction of blast forces propagating toward the top end of Old Second Left Section. Photo taken at location STA-3 on *Flames and Forces Map* (Appendix 5.4-1): view facing approximately N 40° E.

5.4-1d Damage to stoppings

As mentioned previously the direction and severity of damage to stoppings can indicate the direction and severity of a pressure wave. Constructed from 6" hollow concrete blocks and also from Omega blocks they are believed to show damage sustained beginning in the 2 – 5 psi range, depending on their construction. Therefore, undamaged or slightly damaged stoppings were used as a guide to areas that experienced low explosion pressures[7]

Photo 10. Remnants of a stopping in an area outby the seals.

5.4-1e Variable damage

Detailed mapping of the Old 2nd Left sealed area showed varying levels of damage, ranging from mild to severe. The damage was found to be less severe in areas that had a high mining height due to bottom-mining[8] where the resultant mining heights averaged approximately 12-15 feet (as compared with normal mining heights of approximately 6-8 feet). **Section 5.4-3** of this report illustrates bottom-mining in greater detail. Outby the Omega seal location plate bending was predominately unidirectional and away from the seals. Pressures dissipated fairly rapidly,

[7] Or, alternately, where explosion pressures developed more of less equally and at the same time on both sides of the stopping.

[8] Mining of a lower coal split by ramping down and recovering it on retreat mining. Doing so approximately doubled the normal mining height in those portions of the sealed area.

but by the time they reached 59 block[9] they still carried enough pressure to pick up and carry a 1500 pound battery charger approximately 120 ft down the track entry.

5.4-1f An area of conspicuously low damage

The bending of roof pans and plates occurred in areas that were first-mined, only, and this appeared to be the rule for most of the sealed area[10]. The area encircled on **Map 1** was the exception. Comprising an area approximately 250-ft in diameter this area is also shown shaded in yellow on the Flames and Forces Map (**Appendix 5.4**). It was conspicuous in the relatively light damage sustained there in the explosion, compared to the adjacent and surrounding first-mined areas. [11]. The first-force bending directions generally radiated outward from this location. This is also the general location where the explosion is believed to have originated. A brief discussion in **Section 5.4-2** contains more details.

[9] Approximately mid way between spads 3901 and 3923

[10] Except for the top end of Old 2nd Left section which was submerged below water at the time of the explosion

[11] Areas that were not second-mined sustained higher velocities, based on a comparison of relative amounts of damage.

5.4-2 Origin of Explosion

Until mine recovery efforts made it possible for investigators to re-enter the mine there was a general feeling that the explosion may likely have originated in the vicinity of the Omega seals. This belief was based on preliminary information picked up through the mine rescue teams. The seals were gone, and the debris field pointed outby. Some degree of gas build-up around the seals was noted in pre-shift reports. The seals were built at the highest elevation of the sealed area so if the mine gases had stratified according to their densities at the time of the explosion the area around the seals logically would have had higher methane concentrations. Suspicions about lightning suggested that an electrical conductor may have been involved. Incomplete removal of the wire mesh over the seals prior to construction could have provided an electrical path past the seals, but further investigation showed that there was no continuous metallic bridge across the seals.

5.4-2a Origin location

What was found during the course of the investigation, however, was that the explosion originated approximately 1/3 of the way into the sealed area at a distance of approximately 350 feet inby from the closest seal (#1 seal) and 700 feet from the farthest seal (#10 seal).

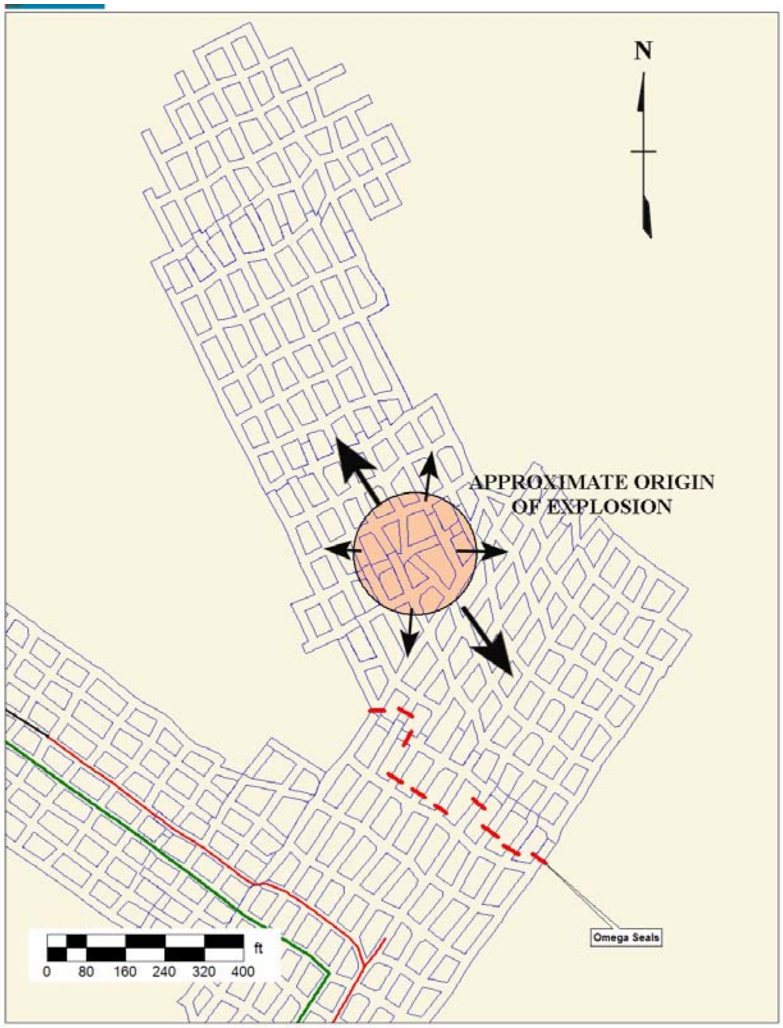
The primary criteria used to arrive at this conclusion were:

1) Conspicuously low damage at this location, despite the fact that there was first mining, only[1]

2) The general direction of the blast forces away from this location, as indicated by the magnitude and direction of bending of metal

[1] Areas that were bottom-mined on retreat showed approximately double the entry height and generally sustained significantly less damage as a result (see 5.4-3).

roof structures, damage to ventilation stoppings, and standing support structures.



Map 1. The explosion is believed to have originated in the vicinity of the area encircled. The initial blast forces generally radiate outward from this location. It is also an area that has relatively slight damage.

It may seem counter-intuitive that the origin of the explosion should be in a location that suffered only minor damage but this is relatively common in underground methane explosions. One way to explain this is that the explosion from a spark ignition in a volume of gas begins slowly and then grows as a *deflagration.*[2] The flame front accelerates and increases in intensity as it consumes fuel and propagates outward from the origin. This behavior is very different

[2] A combustion wave propagating at **subsonic velocity** relative to the unburned gas immediately ahead of the flame, i.e. the burning velocity is smaller than the speed of sound in the unburned gas; *GexCon- Gas Explosion Handbook.*

from a *detonation*[3] from high explosives like dynamite or TNT which starts out at a high velocity at its origin.

The mapping and analysis of the pattern of damage over the next several weeks and months tended to confirm that the first explosive forces radiated outward from this general location (see, **Appendix 5.4-2:** *Flames and Forces Map***).**

Several sets of 5" x 6" x 30" 4-point cribs built at this location remained standing, in whole or in part, after the explosion. The low amount of damage in this area was unique in this respect, except for areas that were underwater at the time of the explosion or had been bottom-mined.

As the investigation continued and the significance of this area became more apparent, investigators began looking in this region for items and features that were unusual or unique in their occurrence and that may have had a connection to the explosion. Two such features were investigated.

5.4-2b The "anomaly"

Near spad 4010 and in the vicinity near where the explosion originated were a series of straight tracks in the roof that could not easily be explained. As such, it was difficult to dismiss their involvement or their significance as they were unique features, at least at that time. Nearby and just north of spad 4028 a second set of similar tracks existed. They are referenced in **Map 1A** as "Anomaly 1" and "Anomaly 2". These tracks were unlikely to be of manmade origin.

Experts were brought in to examine the tracks in-place in the mine roof. Later, samples were cut out of the roof for further analysis and testing. OMHS&T requested a senior geologist with the West Virginia Geological Survey to examine one of these samples. A brief report was written, a copy of which is in **Appendix 5.4-2:** *Evaluation of Roof Anomaly*.

[3] A combustion wave propagating at **supersonic velocity** relative to the unburned gas immediately ahead of the flame, i.e. the detonation velocity is larger than the speed of sound in the unburned gas; *GexCon- Gas Explosion Handbook*.

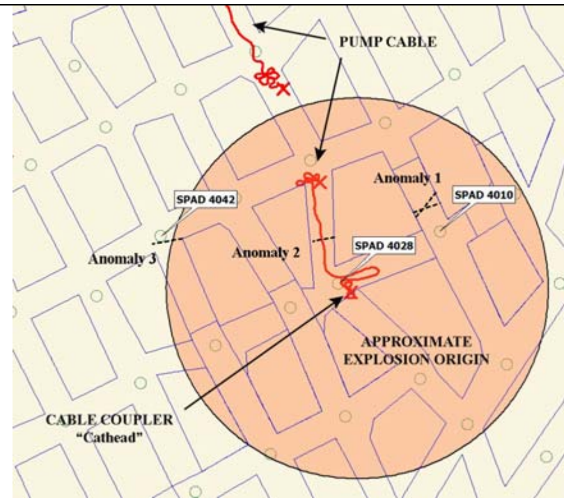


Photo 1. These tracks in the mine roof are near the suspected explosion origin. They were examined in detail for possible evidence of involvement.	**Map 1A**. General location of "anomalies 1, 2, and 3" and part of an abandoned pump cable located within a zone where the explosion is believed to have originated.

Interest waned somewhat when nothing unusual about their composition was discovered. A third "anomaly" was discovered nearby at spad 4042 and at approximately the same stratigraphic level in the roof as the others (diminishing their uniqueness), and geological analysis suggested they were simply an unusually straight cast of a plant fossil. In the end, there was no evidence that these unusual features were anything more than just unusually straight fossils casts.

5.4-2c The pump cable and cable coupler

Another feature that was and continues to be investigated is a pump cable that terminates at a "cathead" (cable coupler) in the general vicinity of where the explosion is believed to have originated under an extensive assortment of roof mesh. This cable was eventually traced back to an abandoned pump that was submerged in water at the top end (back) of the Old 2nd Left section. The cable was broken in three (3) places and was lying with and tangled up among scattered crib blocks and other debris along much of the outby half of its length.

The cable lengths are numbered 1 through 4, with the piece terminating at the cable coupler being length #1. Through the work of John Collins, OMHS&T Inspector, and others, the cable lengths were determined to be approximately as follows:

Lengths of pump cable laying

Cable ID	Length	Comments
#1	199.6'	Outby end terminates with cable coupler near spad 4028
#2	188 '	Intimately tangled with crib blocks on floor
#3	~93'	Brattice curtain looped around outby end at spad 4089
#4	~812'	Inby end terminates at pump 3 breaks inby spad 3713
TOTAL	~1293'	

There is reason to believe that the pump cable was intact in one continuous 1300-ft. length (approximately) at the time of the explosion (see **Appendix 5.4-2**: *Description of Pump Cable Lengths and Associations).* If so, it represents a potentially insulated conductor running parallel to a wire mesh that could have developed a different potential in a lightning strike environment. Lightning produces transient voltage surges on metal structures underground (like the wire roof mesh) and if there is a different ground nearby, or if there are discontinuities in the structure, sparking can occur. The pump cable could also have played no role in the explosion at all. In other instances, potential differences could have been produced simply by the conduction of lightning current through rock strata and discontinuities could have caused sufficiently energetic sparks to ignite critical methane gas pockets[4].

Whether the pump cable played a role in the ignition is not yet known but it remains an item of interest simply because it terminates in the general region where the explosion is thought to have originated.

The pump, pump cable, and wire roof mesh are discussed in more detail in **Section 5.5-3i**.

[4] H.J. Geldenhuys, & A.J. Eriksson; Research into lightning-related incidents in shallow South African coal mines; Proceeding of the 21st Int'l Conf. of Safety in Mines Reseach Institute, October, 1985, p. 775.

5.4-3 Forces on the Omega seals

Ten (10) seals that were built to isolate the mined-out Old 2nd Left Section from the rest of the Sago mine were destroyed in an explosion on the morning of January 2, 2006 and there was little left after the explosion. Small pieces of Omega blocks and gray dust were found scattered a considerable distance outby from the seals. Very little if any of the debris field was found inby the seals, consistent with other evidence which indicates the origin of the explosion was a considerable distance inby the seals. Exactly where the seals had been installed was difficult to discern on casual inspection because hitching[1] of the seals was not required. But by locating subtle perimeter lines of mortar and other means all the seal locations were found and detailed maps of the foundation and remnants were made during the investigation. These are described in more detail in **Section 5.2**.

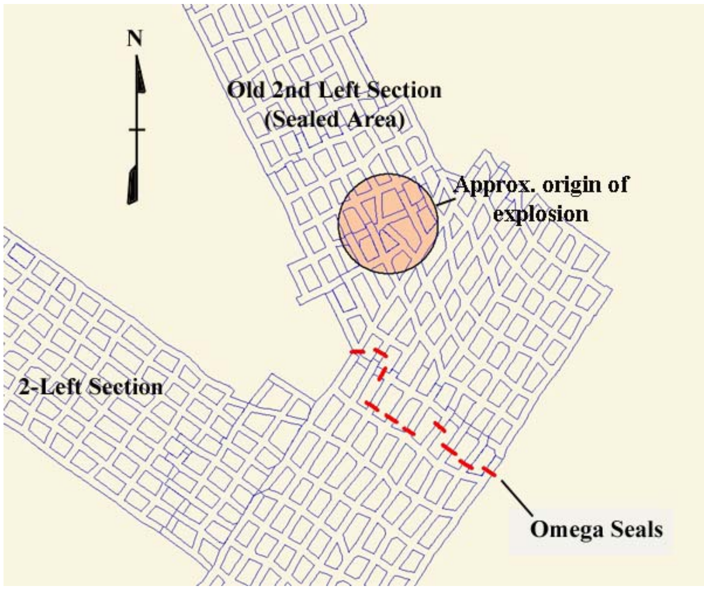


Figure 1. Location of the ten (10) Omega seals that were constructed to seal off the Old 2nd Left Section. Construction was complete on December 11, 2006.

[1] Using mechanical means to create a continuous recessed notch in the mine opening around where the seal is to be installed, being the same width or slightly wider than the seal, and into which the seal is seated.

It is evident that the forces that destroyed the seals far exceeded the ability of the seal to withstand the forces, and the overpressures are believed to have been more than double the 20 psi pressure for which the seals were designed, and possibly much higher. A variety of factors such as the local site conditions and mine geometry can affect the forces that are produced in a mine explosion. These will be considered briefly here, both to serve as a partial explanation as to what may have happened and as information for consideration in future seal constructions.

5.4-3a Applicable regulations on seal construction

In March 11, 1996 a MSHA rule entitled "Safety Standards for Underground Coal Mine Ventilation" defined the standards by which seals were to be built. Among other provisos, 75.335 (a) (2) of that document allows the use of "alternative seals to create a seal if they can withstand a static horizontal pressure of 20 pounds per square inch…" This was the criterion for explosion pressure that was in effect at the time of the previous tests of Omega block seals. This criterion was also in effect when these seals were approved and installed at the Sago mine in December, 2005.

5.4-3b Prior testing of Omega block seals

Seals constructed of Omega blocks are considered "alternative seals." They are made from lightweight fiber-reinforced cementaceous materials, and were originally used for the construction of ventilation stoppings in underground mines. More recently Omega blocks have been approved for use in the construction of mine seals [2].

Results of explosion tests of seals constructed of Omega 384 block are described in publications [3] written between 1990 and 2003 and document the ability of these alternative seals to withstand explosion pressures equal to or exceeding 20 psi static pressure. This standard is the same for coal mines across the country[4].

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[2] WVOMHS&T and MSHA have suspended approval of mine seals constructed from Omega blocks pending further review.

[3] "Omega 384 Block as a Seal Construction Material", C.R. Stephen; 1990, "Designs for Rapid In-situ Sealing," M. Sapko, E. Weiss, J. Trackemas, C. Stephan; 2003.

[4] An exception may be a 1921 law that requires 50 psig for sealing connections between coal mines on federal lands; D.W. Mitchell, Explosion-proof Bulkheads, USBM RI-7581, 1971, p. 2.

Tests of the Omega block seals were performed at the Lake Lynn Experimental Mine (LLEM) which is a retired underground limestone mine that has test entries carved out in room-and-pillar fashion to simulate the layout of a typical coal mine. The test layout is illustrated in a general way in **Figure 2**, consisting of an entry that is a dead-end on one end and open on the other (D) and with cross-cuts A, B, and C at approximately right angles to it.

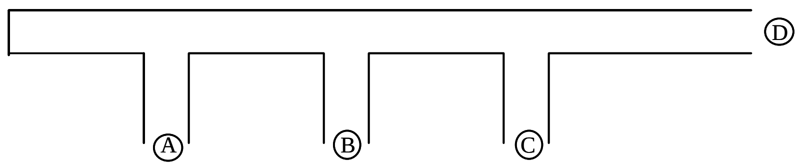

Figure 2. Generalized layout of facility used to test Omega block seals. A, B, and C are cross-cuts. D is an entry.

For the original testing, the Omega block seals[5] were constructed in crosscuts adjacent to an entry where an explosion was created, as shown in **Figure 3**. This was basically an "open chamber" explosion test whereby the blast forces that passed by the crosscuts as they traveled down the entry were allowed to escape from the entry without any confinement. Although this does not simulate the conditions of an explosion in a small sealed area very well, it did satisfy the purpose and conditions of the test at the time-- namely the ability of the Omega block seals to hold forces produced by at least 20 psi static pressure.

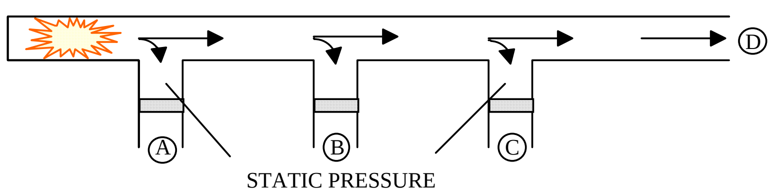

Figure 3. This is a schematic of the "open chamber" test of Omega block seals. Set in the cross-cuts, the seals A,B, and C are subjected to a 20 psi "side-on" pressure from an explosion located at the back of the entry.

The MSHA report documenting these tests stated that "20 psig (was) a suitable performance characteristic for identifying the flexural strength requirements of seals constructed in

[5] First published document for general circulation was entitled: OMEGA 384 Block as a Seal Construction Material, C.R. Stephan, P.E., MSHA, Report No. 10-318-90, November 14, 1990. The actual test at that time involved four (4) seals.

underground coal mines".[6] An explosion test was conducted on Omega block seals on October 10, 1990 utilizing a pressure pulse of approximately 20 psig. Each of the seals survived this test.

On the morning of January 2, 2006, the Omega seals at Sago underwent their own test, and this time all failed catastrophically. Were the original test results wrong? Were the seals constructed improperly? Or was the explosion considerably higher than 20 psi? These are some of the questions investigators set out to answer with the underground mapping effort and with a series of additional explosion tests on Omega block seals that were conducted in the following months at Lake Lynn Experimental Mine.

5.4-3c Additional seal testing at Lake Lynn

In order to re-evaluate the performance of Omega block seals, explosion tests were performed which examined the seal's performance two ways. First, tests were performed on Omega block seals that were constructed using materials and methods in accordance with those recommended by the manufacturer. Second, tests were performed on Omega block seals that were constructed with certain deviations that related to preparation of the seal foundation and application of the mortar in the vertical joints between blocks. This second scenario was intended to address differences with the actual seal construction methods at Sago, whether perceived or proven. A series of six (6) explosion tests were performed between April 15 and October 19, 2006. The results of these tests await final analysis and publication by NIOSH, therefore this report will not attempt to detail these test procedures and outcomes, but some general observations and comments will be offered. Because the test results have not been officially released, the following observations should be considered preliminary.

<u>Summary opinion of OMHS&T with regard to the Preliminary NIOSH (LLEM) Test Results</u>

- The Omega Seals when built as recommended by the manufacturer were capable of withstanding explosion pressures in excess of 20 psi, static.
- The Omega Seals, as they may have been modified in the Sago constructions, were capable of withstanding explosion pressures in excess of 20 psi, static, and

[6] OMEGA 384 Block as a Seal Construction Material, C.R. Stephan, P.E., MSHA, Report No. 10-318-90, November 14, 1990, p. 4.

- In order to replicate the degree of seal damage, roof plate bending, and debris scattering as occurred at Sago, explosion pressures much higher than 20 psi are required.

Among the important things that were demonstrated in the LLEM Tests were the effects of dynamic pressure and pressure-piling on seals that were built across the entry in-line with the explosion[7]. Dynamic pressure is also referred to as velocity pressure or stagnation pressure. Together, static pressure and dynamic pressure comprise the Total Pressure.

Total Pressure = Static pressure + dynamic pressure

In addition to the expansion of gases in a closed chamber which creates an inflation pressure (static pressure) there is a momentum reversal when the gases meet in-line obstructions and are reflected back (**see Figure 4**). The resulting impulse is in addition to and at least as high as the static pressure. This is the dynamic pressure component. In the recent "closed-chamber" tests at LLEM where average static pressures ranging between 24 and 50 psi were felt in the crosscuts (indicated by **A**, **B**, and **C**), the *total pressure* at the seals erected *across the entry* (**D**) saw approximately 51 to 95 psi total pressure (static + dynamic pressure), respectively. Hence, at this particular range of pressures, and as a general approximation, the forces on an *in-line* seal were about 2x the average *side-on* explosion pressures. [8]

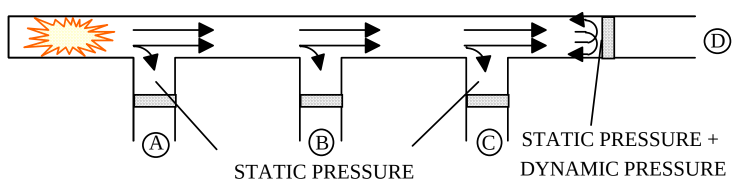

Figure 4. This is an example of the "closed chamber" explosion. A seal placed in-line with the explosion in entry (D) is subjected to static pressure as well as dynamic pressure. In recent explosion tests preliminary results indicate a seal at location D experienced approximately 2x the maximum pressure felt at locations A, B, or C.

When a blast wave impacts a structure at zero angle of incidence, the forward-moving air molecules in the blast wave are brought to rest and are further compressed, inducing a reflected overpressure on the wall which is of higher magnitude than the incident overpressure. When the incident blast wave from an explosion strikes a seal head-on it is reflected. When such reflection occurs, the seal surface will experience a single pressure increase since the reflected

[7] "Pressure-piling" is a local dynamic effect which can cause high local explosion pressures; *GexCon- Gas Explosion Handbook*.

wave is formed instantaneously. The total reflected overpressure at **D** will be more than twice the exact value of the peak overpressure of the incident blast wave as seen in **A, B,** and **C** (see **Figure 4**).

Test six (6) at LLEM produced pressures at the seal at D (**Figure 4**) in the range of 95-100 psi[9]. Only at that level of explosion pressures did the magnitude of damage to roof pans and the amount of damage to seals begin to approach (but not yet equal) that observed at Sago.

5.4-3d The effects of obstructions and bottom-mining

The effects of turbulence and velocity increases at venturi-like[10] constrictions of the mine passages at Sago could also have been a factor contributing to the magnitude of pressures developed by the explosion. As described above, the pressure from a propagating explosion is comprised of two components: static pressure (the inflation pressure of expanding gases equalizing in all directions) and dynamic pressure (the momentum exerted by wind velocities)

A simple expression for dynamic pressure is given by:

$$\text{Dynamic Pressure} = \tfrac{1}{2}\rho V^2$$

where, ρ = density of the air,
V = wind velocity

When the initial pressure wave from a blast propagates down an entry it picks up speed as it consumes fuel. Turbulent mixing of the air and fuel significantly increases the velocity of the flame. Near the location of the origin of the explosion the initial velocity of flame propagation is small, causing relatively little damage from the dynamic pressure. In the case of a methane explosion a flame front moving along a mine entry through areas of bad top, ground support structures, gob piles, constrictions, and other turbulence-enhancers will experience flame acceleration and corresponding local increases in overpressures.

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8 In closed-chamber explosions, some reflection pressures from the in-line seal were felt and these effects must be more closely examined when the official data are available.

9 A preliminary estimate. Also, the seal at location D in Test 6 was an Omega block seal constructed by methods intended to replicate the actual Sago construction.

10 A *venturi* is a tube with a gradually-reduced diameter along its length. In fluid mechanics it is a way to increase pressure without increasing the rate of flow.

Among the factors contributing to the strength of the explosion, and which often are not addressed in seal design, are the effects of hydraulic jumps and turbulence enhanced mixing of air and fuel as the blast wave propagates inside the mine.

A series of ramps and drop-offs in the sealed area of the Sago mine were created during bottom-mining of a lower coal bench on retreat. Although the rock parting separating the two seams was thin enough to allow the top seam to be recovered on advance, it was not feasible to mine the lower seam at the same time because the result is a mining height of approximately 12-15 feet. Mining this entire sequence on advance could possibly have exposed mine personnel to higher risks from falling coal or rock. A plan was devised and followed to recover the bottom coal bench on retreat, where feasible. With the mine roof already bolted the length of exposure to risks associated with working around high coal ribs and high top were thereby minimized.

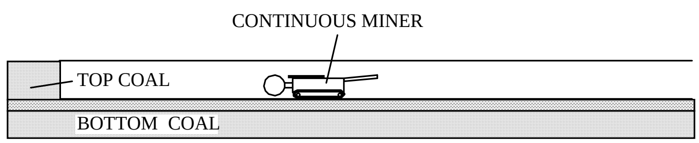

Figure 5. Top coal is mined on advance. Bottom coal is not mined until mining advance in the section is complete and the section retreats. Mining the bottom coal on retreat reduces risks to personnel working under high coal ribs and high top that tends to get weaker with time.

An illustration of this is given in **Figures 5, 6,** and **7**. The top bench was mined first throughout the entire area before bottom-mining commenced (**Figure 5**). Mining of the bottom seam began only as the section was retreating.

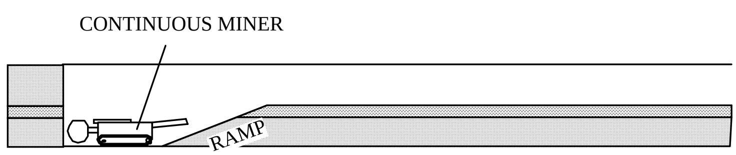

Figure 6. Bottom coal is mined on retreat. The continuous miner ramps down at an angle of approximately 15 degrees and mines through the shale parting to the bottom coal seam in runs of approximately 80 – 300 feet, depending on conditions.

In a simplified way, this is illustrated in **Figure 6** where the continuous miner backs up a prescribed distance and cuts a ramp down off the top coal bench, and mining proceeds until the end is reached. This process repeats and as shown in **Figure 7** occasionally results in small stumps left at the end of a bottom-mining run. Ultimately, all the bottom coal that could be feasibly mined was removed and the ten (10) Omega Seals were constructed outby the last ramp-down in an area that had been first-mined, only.

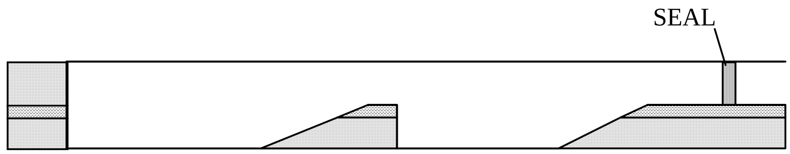

Figure 7. After bottom mining is complete, a series of ramps and drop-offs remain. Ten (10) seals were installed at the top of the last ramp which is the end of where bottom-mining occurred.

Bottom-mining is a fairly common-place procedure when the coal and parting thickness make it feasible and is an accepted practice to facilitate the efficient and safe recovery of all the coal that can be recovered. Bottom-mining is not believed to have played a role in the initiation of the explosion, however the resulting geometry of the mine floor may have facilitated an acceleration of the deflagration as the blast propagated through the region because of the enhanced turbulence produced on the way to the seals. In addition, the last ramp before the seals may have significantly increased the force of the explosion, perhaps by as much as a factor of 4.

Referring to the previous equation that gives a simplified approximation of the dynamic pressures of flow as a function of the air density and velocity,

$$\text{Dynamic Pressure} = \frac{1}{2}\rho V^2$$

a second equation gives the relationship between cross-sectional area A, velocity of the wind from the blast, V, and the volumetric flow rate Q.:

$$Q = V \times A$$

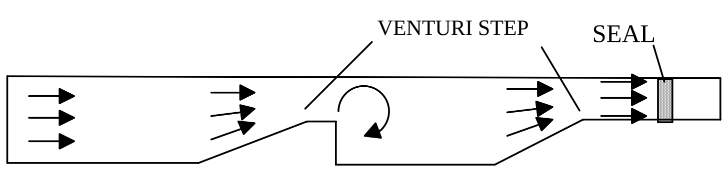

Figure 8. During the explosion blast forces traveling down the entry may have been enhanced by the turbulence and local compression and expansion effects created by the remnant ramps of bottom coal. These forces were obstructed by the seals.

The blast forces were not as great in the bottom-mined areas, as evidenced by the comparatively low damage to roof pans and plates compared to locations that were first-mined only. However, at hydraulic jumps, like at the last venturi step, just inby the seals, (**see Figure 8**) as the cross-sectional area decreases by ½, the flow velocity increases (theoretically) by a factor of 2 in order to keep the same volume of flow (Q) through the constricted region[11].

$$Q = 2V \times ½ A$$

And the dynamic pressure increase by a factor of 4, i.e.

$$\text{Dynamic pressure} = ½ \rho V^2 = ½ \rho (2V)^2 = 4 \times ½ \rho (V)^2$$

Therefore, it is possible that the venturi step just inby the seals could have increased the dynamic pressure by a factor of 4.

It should be pointed out that although this provides a good approximation for the effects of dynamic pressure it is not strictly correct because these are equations for incompressible flow and air is compressible. Because of this the actual velocity increase at the venturi step is probably less than a factor of 4, but compression would result in increased air density which would in turn increase the amount of actual impulse to the seal. Further, what is shown as static + dynamic pressure in **Figure 4** is actually recorded as static pressure at the seal, because wind velocity becomes zero (0) as the blast wave is stopped before reflecting off the seal. The effective total pressures at the seal are therefore reported as *reflected pressure*, which is a value that is somewhat higher than the value for static + dynamic pressures. The net effect of these factors is that, for comparison and illustrative purposes, and at a range of pressures equivalent to as much as a 50 psi static "side-on" pressure wave, a 4-fold increase in additional pressure (we will call it dynamic pressure) is due to the resultant increase in velocity to a blast wave propagating through a ramp that is ½ as high on the top from what it is at the bottom.

Turbulence effects may have also been present where the cross-cuts and bottom-mined entries intersect (**Figure 9**). This is based on the damage that was observed at a number of such intersections where the plate damage was extreme, with little if any damage in the nearby bottom-mined entries between the cross-cuts. Additional turbulence features that could enhance combustion acceleration and the flame speed include things like gob piles that restrict the entry height and areas of bad or uneven roof.

[11] Bottom-mined areas were approximately double the cross-sectional area as normal mining height at the seals.

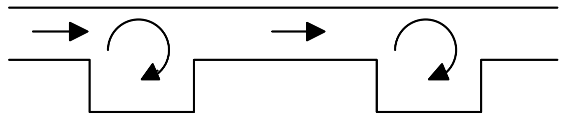

Figure 9. Because little or no bottom-mining was done in crosscuts the propagation of blast forces through crosscuts also encountered turbulence and compression/expansion zones as successive bottom-mined entries were crossed.

5.4-3e Additional evidence of large reflected pressures

As discussed in **Section 5.4-1** there were areas of severe damage to roof pans and plates that looked as if high pressures, temperatures, or both had been at work, generally deforming the pans around the bolt heads in a way that left them looking very much like garden flowers after a frost. In fact, one investigator coined the term "wilted tulip" which is perhaps as good a term as any to describe them.

These areas were noted in red shading on the *Flames and Forces Map* **(Appendix 5.4-1)** and are similarly indicated generally on **Figure 10**. After notes and locations of this style of plate damage were compiled on a map covering the general region of the sealed area it became clear that this type of damage occurred mainly in areas of first-mining, only, and where blast waves impacted at and created pressure reflections at solid boundaries, such as along the outer perimeter of roof falls and areas where entries dead-ended or were butted-off against solid. Also, notably, the area inby each of the ten (10) Omega seals similarly exhibited this degree of pan deformation

Therefore, we can draw two conclusions: first, the explosion forces were of such a magnitude that reflected pressures were very significant (much greater than 20 psi), and second, that the seals did not fail at the instant of pressure arrival, but rather held on momentarily to effectively reflect and amplify the initial incident blast pressure. In the end, the seals did let go catastrophically, but apparently not until presenting resistance.

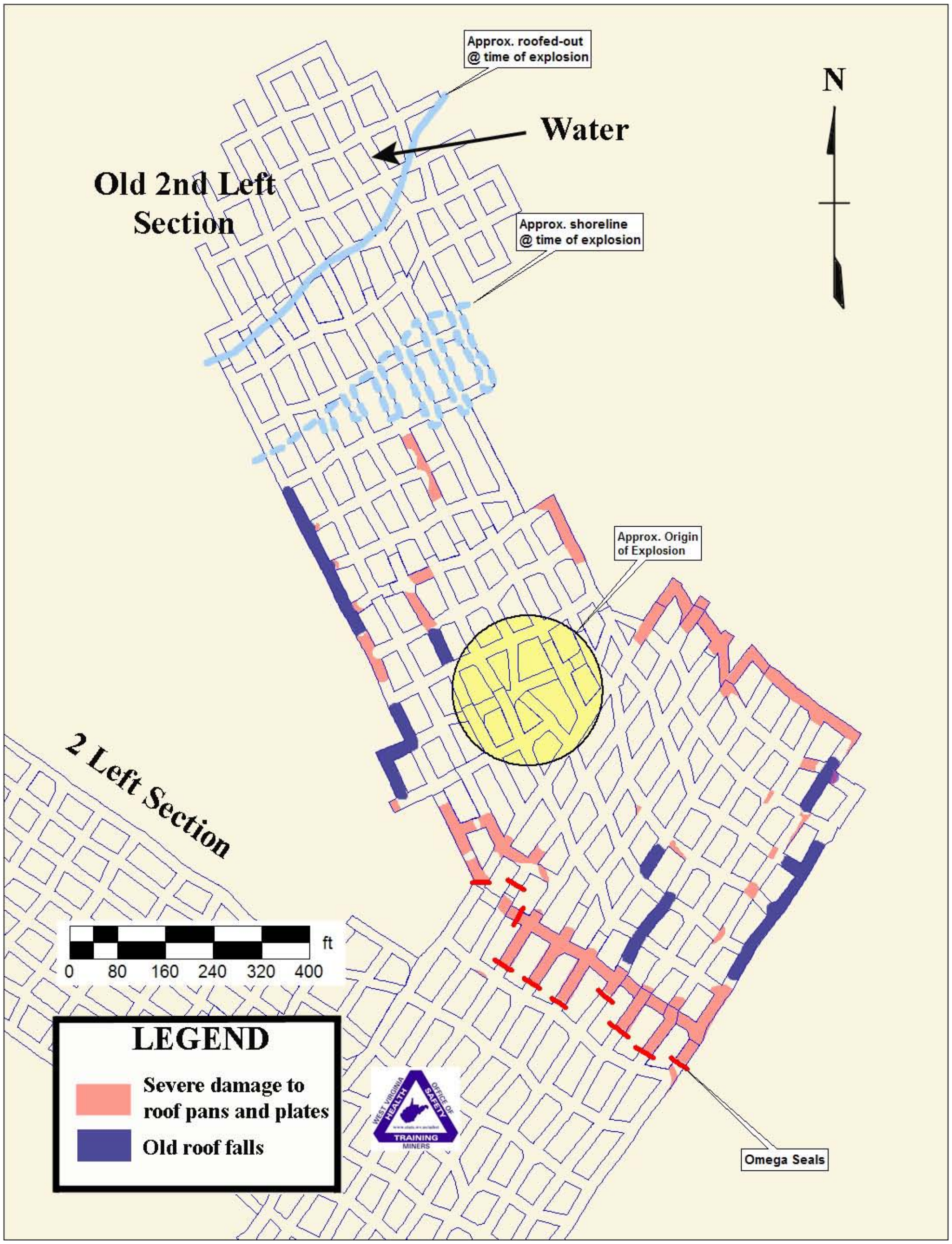

Figure 10. Areas or severe plate damage are viewed as indicators of high dynamic and reflected pressures. Areas shaded in red appear to indicate zones of encountered turbulence and/or obstruction in the path of the blast wave propagation.

5.4-3f Magnitude of explosion pressures

The balance of evidence, both experimental and observational supports the conclusion that the explosion at the Sago mine exceeded 20 psi. There was in fact more damage than can be adequately explained with even a 50 psi explosion. At this writing there is reason to suspect that explosion pressures in excess of 100 psi may have been developed.

A preliminary report by Dr. Steve Sawyer describes the results of bending tests performed on belt hangers and compares them against the measured bending on the same type of structures as observed in the roof both inby and outby seal #6. This preliminary report suggests pressures of at least 60 psi and possibly exceeding 92 psi.[12]

Summary

Mine opening geometry may play a more significant role in the development of explosion pressures in small-volume sealed areas than previously thought. The effects of bottom-mining in Old 2nd Left Section, and the resulting ramps that were created just inby each of the ten (10) Omega seals, may have enhanced the explosion pressures on those seals by at least a factor of 4—perhaps more. In addition, floor obstructions like gob piles, abrupt ledges, and areas of bad top may increase turbulence in an explosion, thereby increasing the combustion rate of a methane explosion and accelerating a deflagration toward a more destructive mode such as a transition to detonation.

Preliminary empirical evidence developed in explosion tests on seals this year at LLEM seems to indicate that even in the absence of the effects of bottom-mining, explosion forces from a blast that exerts 20 to 50 psi static pressure in a “side-on” impact from the passing pressure wave will exert total pressures of at least twice that much in “head-on” impact with a seal or other significant obstruction that is in its direct path. Added together, these factors may suggest our understanding of blast forces as they are applied to seal design and construction may need to be re-evaluated. Further study by way of seal explosion testing and computer simulations utilizing properly validated modeling methods would help increase our understanding of these geometry effects in order to develop more appropriate seal designs.

[12] Preliminary Forensic Analysis of the Peak Pressures on the Seals During the Sago Mine Explosion; Dr. S.G. Sawyer, April 28, 2006—revised May 1, 2006.

5.4-4 Methane Concentrations

From the time the last Omega block seal was completed on December 11, 2005 until the time of the explosion on January 2, 2006 approximately 22 days had elapsed. Concentrations of methane gas (CH_4) emanating from fractures and pore spaces in the coal and surrounding rock strata are believed to have been emitted at an average rate of approximately 18,124 ft^3/day, therefore an estimated 398,740 ft^3 of methane had accumulated by January 2. If this amount was evenly distributed within the sealed area of Old 2nd Left Section at the time of the explosion the average concentration would have been about 13.1 % .

A mine atmosphere is considered to be "outside the explosive range" for methane once the concentrations exceed 15% and/or the oxygen is below 12% [1]. Because the explosion occurred we know for certain that the atmosphere behind the Omega seals had not yet reached these limits on January 2, 2006. To determine the amount of methane involved a series of studies and calculations based on rates of methane liberation and the mass balance calculation of the combustion products were performed.

Two (2) studies were performed by MSHA to estimate the quantity of methane gas behind the Omega seals at that time of the explosion. The raw data from these studies have been used in this report to estimate volumes and concentrations of methane gas at two points after the explosion.

An additional analysis was done by OMHS&T to determine the combustion products that were emitted by the mine after the explosion to estimate the volume and concentrations of methane at the time of the explosion.

5.4-4a Gas liberation tests

Two (2) series of airflow and gas concentration studies were conducted by MSHA and Alpha Engineering to determine the **current** rates of methane liberation in the area of the mine behind the seals. These tests included:

1) A 49-hr. study from February 7 to February 9, 2006

2) A 21-hr study from March 2 to March 3, 2006.

These data were made available to this agency and have been used to help construct a methane liberation rate chart (**Figure 3**).

<u>Method</u>

The quantities and concentrations of methane were measured continuously over a 49 hour period starting at 8:00 AM February 7, 2006 and ending at approximately 8:00 AM February 9, 2006. Two exhaust boreholes that had been drilled earlier to ventilate the sealed area after the explosion were each measured hourly to determine the quantity of airflow and the methane concentrations. The air inlets to the Old 2nd Left (a.k.a the "sealed area") were measured at the same time, and the methane concentrations were determined by subtracting the concentrations at the inlet from the concentrations at the outlet, multiplied by the rate of flow through the area.

The total quantity of methane liberated during the 49-hr. was estimated to be 31,876 ft^3 which is equivalent to a methane liberation rate of 15,613 ft^3/day.

Data from the second study conducted by MSHA was for a period of 21 hours starting at 8:00 AM on March 2, 2006 and ending on March 3, 2006 at around 5:00 PM[2]. Methane concentrations were computed in a similar fashion.

The total quantity of methane that was liberated during the second study was estimated to be 11,430 ft^3 which is equivalent to a methane liberation rate of 13,063 ft^3/day.

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[1] If the oxygen content of the air is reduced down to 12% it cannot form an explosive mixture with methane; *Fire Gases and their Interpretation; P. Mckenzie-Wood, J. Strang; The Mining Engineer, June 1990.*

[2] Approximately 13 hours of no data collection occurred during the sample period.

Accuracy Limitations

The accuracy of these calculations is limited to the accuracy of the measurements and is subject to uncorrected errors in the data, discrepancies, or revisions, and/or OMHS&T interpretation of those data. Some corrections to the data were made, for instance, by replacing values of zero with values of "nearest neighbors" during the periods in which there were no sample data.

These data are given in **Appendix 5.4-4:** *MSHA Methane liberation studies #1 and #2).*

5.4-4b Methane concentrations calculated from the estimated quantity of explosion combustion products

Because the liberation tests do not actually show specifically what the liberation rates were in the 22 days between the date of seal completion of the seal and the date of the explosion, a mass balance calculation was performed for the combustion gases that were ventilated from the mine following the explosion. These results were then compared to the MSHA estimates to see if they fit into a statistical trend in the coal degassing rate over time.

The results of the mass-balance analysis suggests a methane volume of approximately 398,740 ft^3, before the explosion, which implies an average liberation rate over the period of 18,124 ft^3/day or an average methane concentration at the time of the explosion of approximately 13.1%[3].

For purposes of this calculation the fuel for the explosion is considered to have been entirely methane gas, although some minor amounts of other fuels could also have been consumed. The predominance of methane is indicated by very minor C_2H_4 and a Trickett's Ratio of .4 - .5 [4]. Estimates of the total volume of carbon dioxide (CO_2) and carbon monoxide (CO) that were ventilated out of the mine portals were used to infer the original volume of methane that was consumed [5]. The gas concentrations of CO and CO_2 are based on the best data available at the time the readings were taken. Hand-held gas detectors provided CO data values from approximately 8:00 AM January 2, 2006 until 2:45 PM that afternoon. Data for CO_2 were

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[3] Assumes uniform gas distribution. OMHS&T estimates the volume of the sealed area is 3,033,818 ft^3.

[4] *Methods to Determine the Status of Mine Atmospheres- an Overview*; R.J. Timco, NIOSH; R.L. Derick, Twentymile Coal Company; Proceedings from the Annual Meeting of SME, 2006. *Mine Fires*; D.W. Mitchell, 1996.

[5] CO_2 concentrations were reduced by 375 ppm to adjust for ambient concentrations.

unavailable so values were estimated from rate of change of CO concentrations over this time period.

Method

The molecular weights of CO and CO_2 were calculated and converted to kg/mole at 1.03 bar and 59-degrees F. The volumes of CO and CO_2 gases coming out the #1 Main Return for a 60-hour period following the explosion (in 2-hour increments) were totaled using an average of seven (7) flow readings[6] out this entry and converted to total weight using densities at 1.013 bar and 59-degrees F.

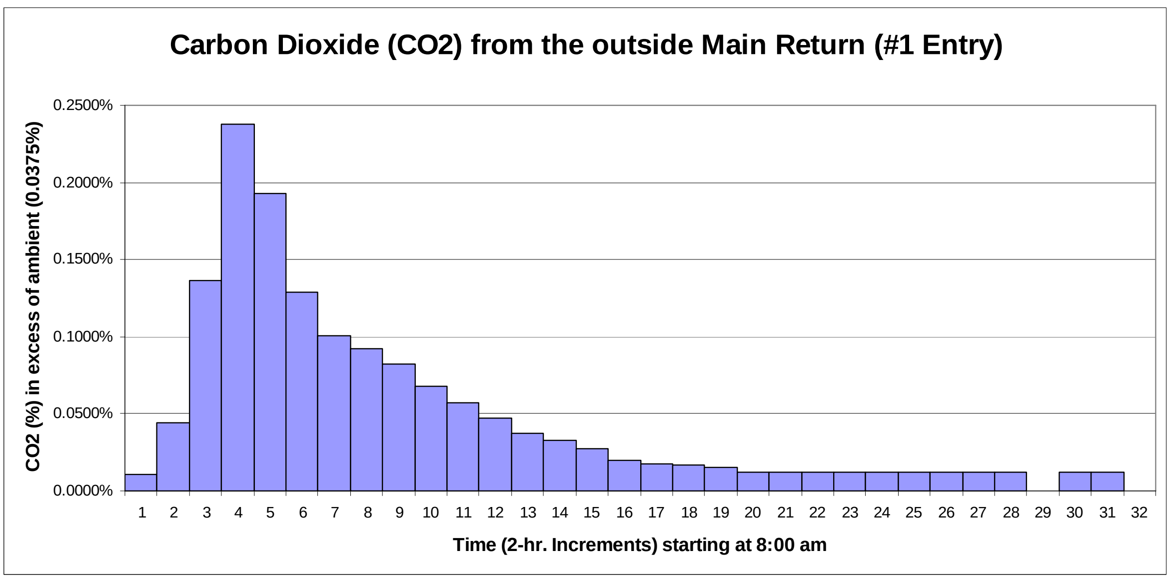


Figure 1. Carbon dioxide (CO2) % concentration as measured at the Main Return (#1 entry). Time units are shown in 2-hr. increments over a 60-hr period starting at 8:00 am on 1-2-06. Volumes have been adjusted for the 375 ppm ambient air concentration.

Next the sum of the CO and CO_2 masses were converted to moles to provide a basis for the moles of CH_4. Volume of the parent methane was then determined by converting back to weight and then finally to gas volume at 1.03 bar and 59-degrees F. A summary of these calculations is included in **Appendix 5.4-4:** *Mass Balance Calculations.*

Accuracy Limitations

[6] Taken between 1-2-06 8:40 AM EST and 1-2-06 9:37 PM EST.

Reliability of these data are limited by the accuracy of the readings of gas concentration, flow volumes coming out the exhausting return and neutrals, and the estimated volume of the sealed area, and the assumptions used in the conversion.

A computer simulation of the pre-explosion ventilation parameters was performed by MSHA (see **Appendix 5.4-4:** *Pre-explosion airflow)* and suggests the blowing velocity of the intake fan in the #5 entry was approximately 172,300 CFM just prior to the explosion. This was used as a starting point, but because of the damage to stoppings and other ventilation controls from the explosion the short-circuits in air which existed at the time of the explosion would decrease the resistance by some factor. For purposes of these calculations the flow rate was assumed to be 185,000 CFM.

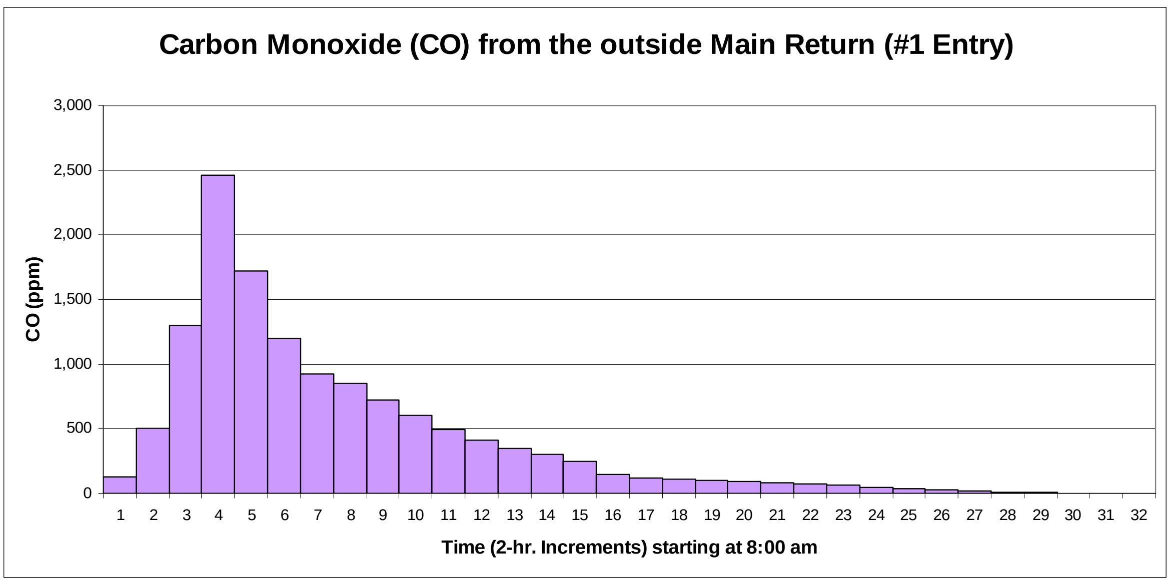


Figure 2. Carbon monoxide (CO) concentrations expressed in "part per million" as measured at the Main Return (#1 entry). Time units are shown in 2-hr. increments over a 60-hr period starting at 8:00 am on 1-2-06.

The sensitive variable in the mass balance calculation is the #1 Main Return flow volume (for which we have only a few actual readings). The #1 Main Return is estimated to have discharged on average approximately 40% of the total exhaust volumes and 85% of the exhaust concentrations during the 60-hr. period. The remaining volumes and concentrations were assigned to the #2, #3, and #4 entries.

Concentration allocations are based on approximately nine (9) sets of hand-held gas detector readings taken at approximately the same time from each of the #1, #2, #3, and #4 entries.

5.4-4c Putting it all together

As a final step the two (2) MSHA and one (1) OMHS&T values for average daily methane liberation volumes were plotted on a chart for comparison. This chart (**Figure 3**) shows a linear rate of decline for methane liberation over the three (3)-month time period.

To check the statistical correlation of the data a linear regression function in Excel was used to generate a best-fit curve and report the equation that describes the gas liberation rate as well as an R-square value (see **Appendix 5.4-4:** *Mass Balance Calculations* for more details**).**

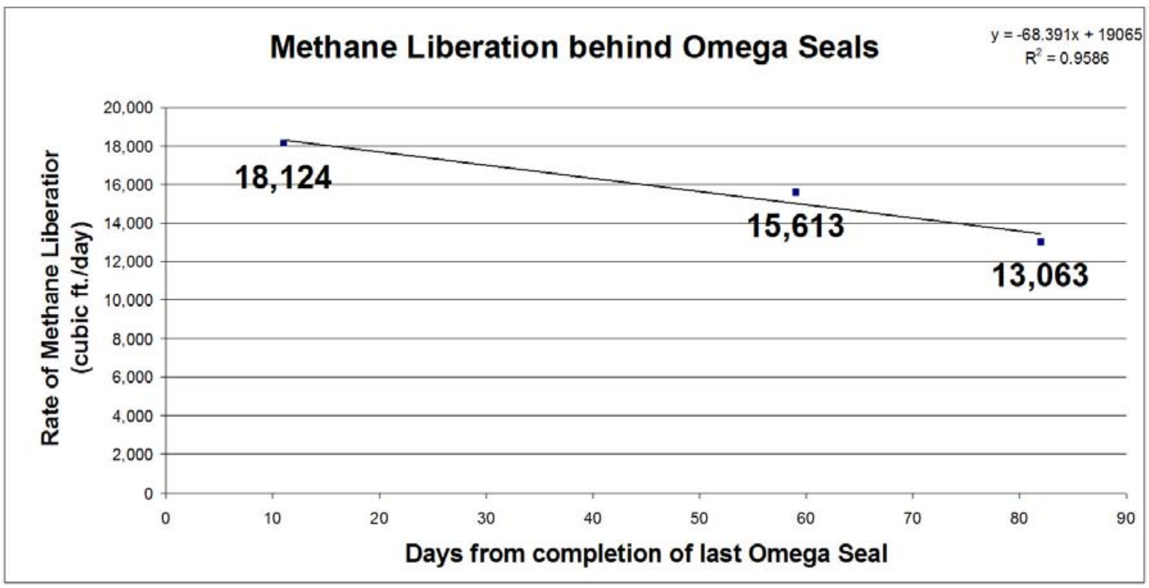


Figure 3. This graph shows the history of average daily methane emissions over time within the sealed area of Old 2nd Left, as determined by an analysis of gas data recorded at Sago Mine.

Findings and Conclusions

An analysis of the total quantities of CO and CO_2 combustion products measured and inferred from the Sago explosion gives the following statistics:

1) The average daily methane liberation rate behind the seals during the 22 days[7] that they were up was approximately 18,124 ft^3 per day.

2) Assuming the methane was distributed uniformly in the atmosphere behind the seals the average concentration was approximately **13.1%**. It has not yet been determined to what extent the gases were stratified so in some regions the concentrations may have been higher than in others.

3) Incorporating the gas liberation data from MSHA suggests that the rate of methane liberation in the sealed area was highest at the time it was sealed and since that time the rate has gradually decreased in volume.

4) Although only three (3) data points are available, these points closely fit a trend given by the linear regression equation:

Rate of Methane liberation[8] = **-68.391x +19,065**

Where "**x "** is the number of days since completion of the Omega seals.

[7] Construction of the seals had been completed 22 days prior to the explosion.
[8] In cubic feet per day

5.4-5 Coking Tests

The extent of the flame can be inferred from the evidence of coke. Coke is the product of the partial combustion of coal in an oxygen deficient atmosphere. In the process, volatile constituents of the coal (including water, carbon monoxide and coal-tar) are driven off and fixed carbon and residual ashes are fused together.

The temperature required for coking to commence varies with the coal but is on the order of 700º F. The flame temperatures during an explosion are approximately 1800º F. Coal exposed to explosion flame does not always coke. Research has shown that coking does not occur when high flame speeds are achieved because the coal is only exposed to these elevated temperatures for several milliseconds. Coking also does not occur beyond the extent of flame.

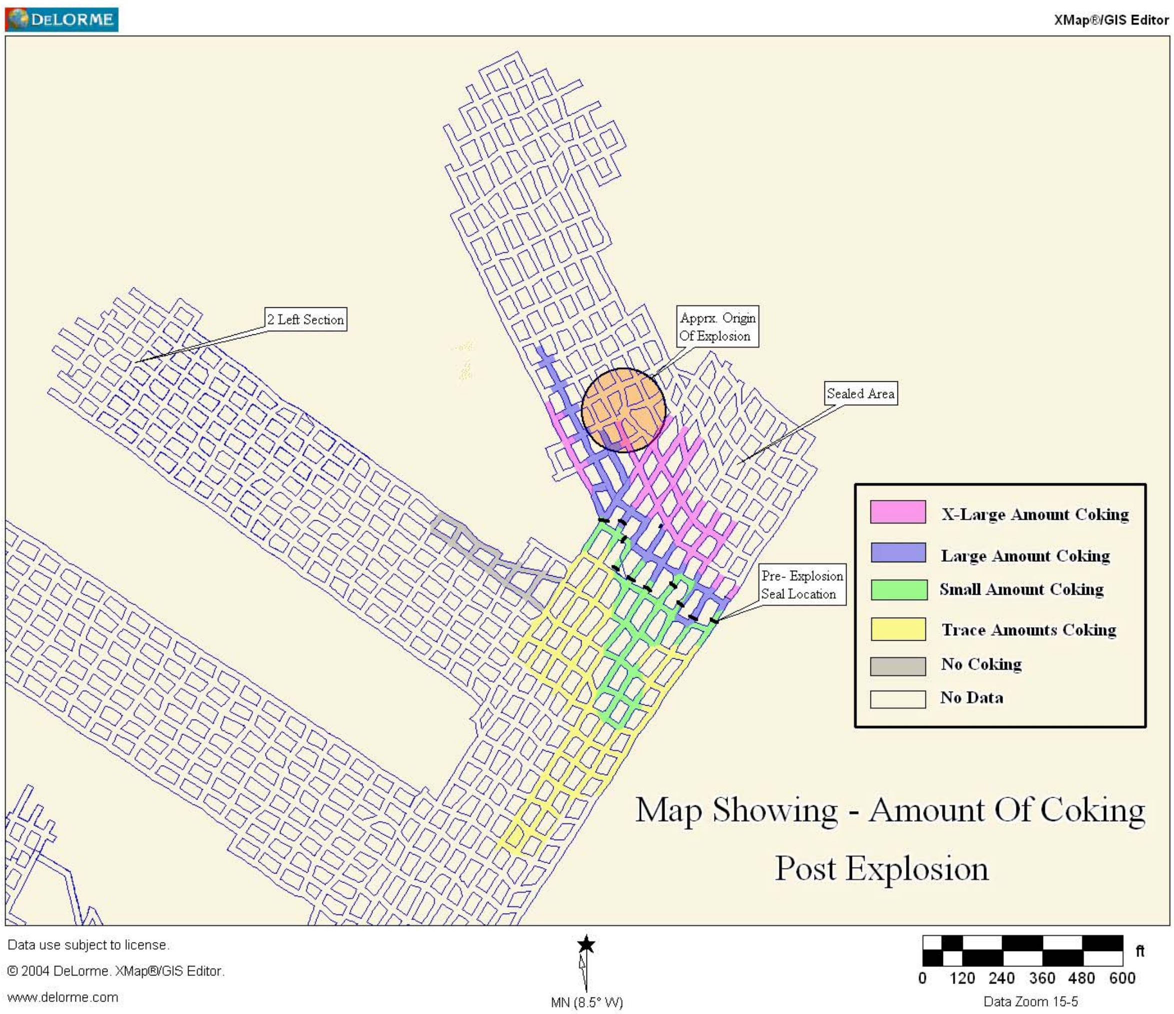
Coke can only be formed in mine dust that has an incombustible content less than 50 percent prior to the explosion. Explosive forces do however, cause dust dispersion and transport during an explosion with oscillating pressure waves reflected from the surfaces of the mine allowing for dusts and other debris to be moved in all directions.[1]

The Alcohol Coke Test used by MSHA provides one of five results concerning the amount of coke present; x-large, large, small, trace and no coke. The amount of coke is related to the duration that flame was above 700º F and the availability of combustible coal dust. The MSHA analysis on dust samples from approximately 400 locations indicated that the presence of coke inby and outby the old-second-left seals. The highest amount of coke occurred inby the seals within the old-second-left section. Within the old-second-left section the greatest coke was found immediately outby the approximate origin of the explosion in the direction of the seals.

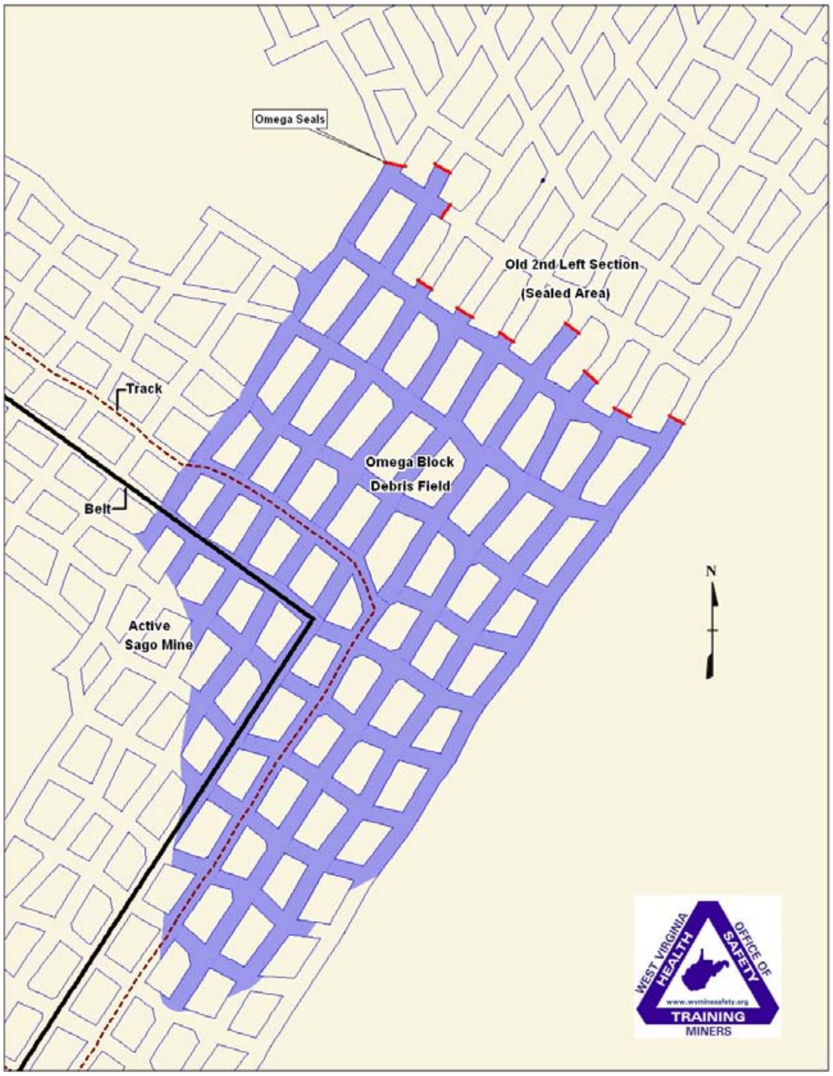
[1] From MSHA document CAI-2001-20-32, Fatal Underground Coal Mine Explosion at No. 5 Jim Walter Resources September 23, 2001

In analyzing the coking map (**Map 1**) the area of x-large coke amount extends from the approximate origin of the explosion outby towards the seals. The distribution of debris (**Map 2**) shows that the bulk of the debris was scattered in a pattern that closely mirrors the coke patterns.

This information supplements and does not contradict the information from the flames and forces.



MAP 1: The amount of coal coking is an indicator of the amount of heat and duration of that heat. The symmetry of the coking trends is similar to the symmetry of the Omega block debris field (see MAP 2).



MAP 2: This illustration shows the approximate distance and symmetry of the debris field created by the ten (10) destroyed Omega seals.

5.5 Cause of Explosion

5.5-1 What caused the explosion?

A variety of possible causes were considered and evaluated as part of the investigation into the January 2, 2006 explosion at the Sago mine. Ignitions caused by open flame, spontaneous combustion, roof falls, faults in the mine electrical systems, and lightning were suspected and considered. The following summarizes the findings of each. Lightning is the probable cause of the explosion.

5.5-1a Open Flame

The seals had been completed for a period of 22 days when the mine explosion occurred, making it unlikely that an open flame of man-made origin could have been the source of the ignition which is known to have originated within the sealed area itself. No evidence was found of any batteries, smoking materials, or other potential ignition sources in or around any area that could have been the source of the ignition.

5.5-1b Spontaneous Combustion

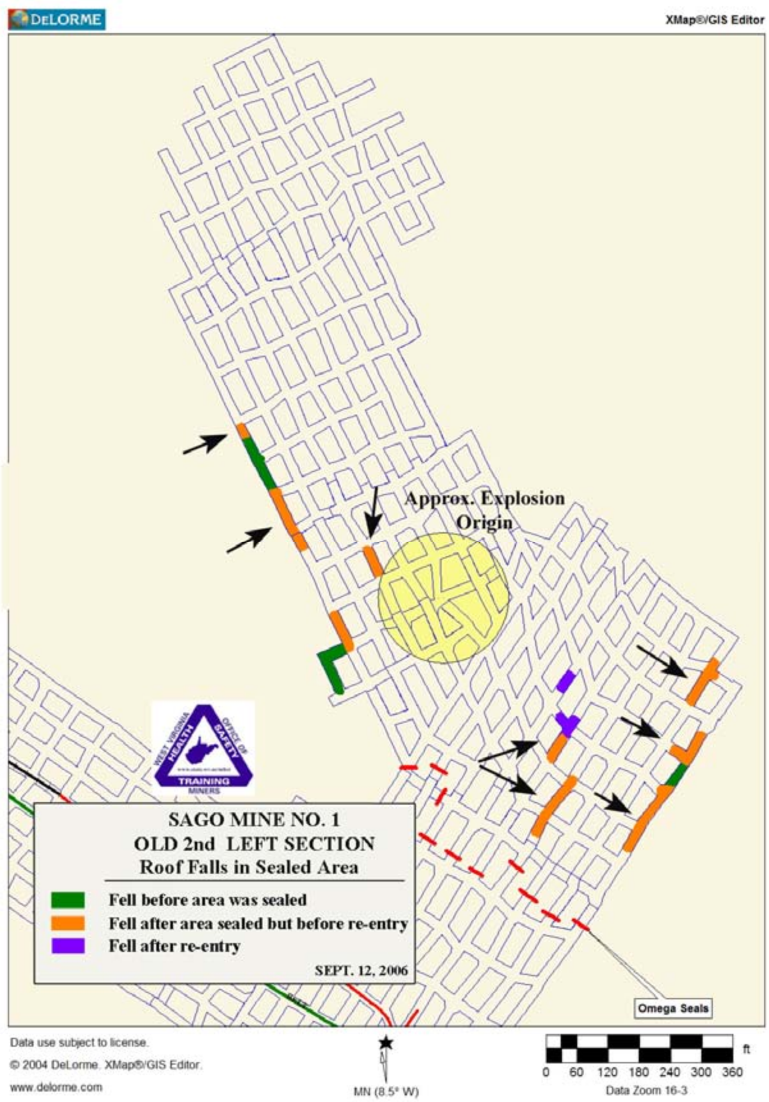
Spontaneous combustion is a potential problem with coals that have chemical properties that enable endothermic reactions to heat the coal to the point that it can smolder and eventually catch fire without an outside ignition source. Western coals that have a high moisture content and a low fixed carbon-to-volatile ratio are susceptible to spontaneous combustion. This phenomenon is not without precedent in the Eastern U.S. but it is much less common. Documented cases exist where oxidation of reactive constituents in the coal such as iron sulfides[1] can lead to self-heating. Typically, however coals that are susceptible to spontaneous combustion generally show signs that are recognized early in mining, i.e. the coal has an established history of spontaneous heating in open stockpiles or gob piles. Further, spontaneous combustion would not go away after the explosion. It would continue to smolder and would

[1] Pyrite and marcasite are the most common

likely be very difficult to extinguish. There has been no known history or evidence of spontaneous combustion at the Sago Mine either before or after the explosion.

5.5-1c Roof falls

There are several roof falls that have been identified and mapped within the sealed-off area of the mine. **Map 1** illustrates the location of known roof falls. Rocks of certain types[2] are capable of creating sparks if they strike metal objects such as roof bolts.



Map 1.—The location of known roof falls in the area behind the seals. Arrows indicate those falls which occurred after the seals were built but before mine re-entry.

2 Quartzose sandstone or chert are two such rock types that have sparking potential characteristics.

Several of these falls are known to have occurred either before the explosion or after the explosion, and so have been discounted. Of the remaining falls (indicated with arrows), only one (1) is in the region where the balance of the evidence indicates the explosion originated.

Photo 1. Roof fall in Old 2nd Left Section. In some cases, a determination of whether the fall occurred before or after the explosion could be made by the relative abundance of soot covering it. A heavy soot typically covered falls that occurred before (or possibly during) the explosion.

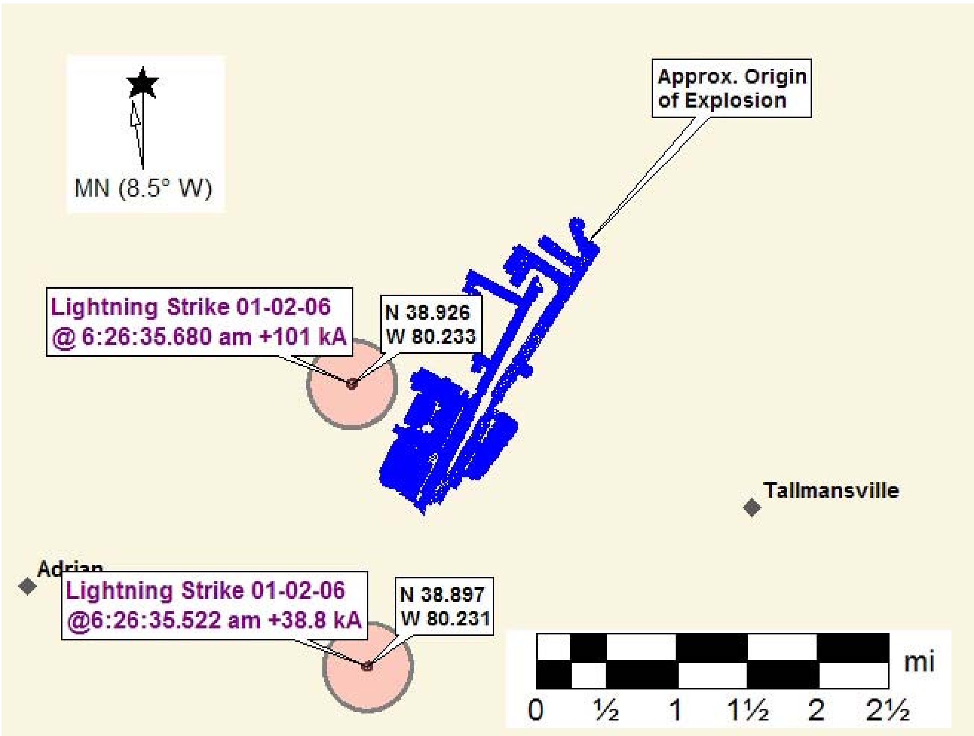
The domed top of the fall contains inter-bedded layers of sandstone that, under the right conditions, could have produced the necessary spark. However, after examining this area several times since the explosion, no evidence has been found that would indicate that the ignition started there. The balance of the inferred propagation directions of the blast favors a point-of-origin farther to the southeast.

5.5-1d Mine electrical system

No evidence was found of any electrical equipment malfunction or failure of electrical circuits that could have caused ignition of the explosive mixture of methane and oxygen behind the seals. No apparent lightning damage was found in any electrical equipment or in the electrical installations on the surface or underground[3]. Testing is still ongoing in several different areas trying to determine the cause of the explosion. Deficiencies were found, both on the surface and underground, resulting in 33 non-contributing violations being issued by the West Virginia Office of Miners' Health, Safety & Training. (**Appendix 5.1:** *Statistics and Fact Finding).*

5.5-1e Lightning

A severe winter electrical storm passed through the Sago region the morning of January 2, 2006. Shortly before 6:30 AM EST, the storm produced several intense lightning discharges near the mine, and mine personnel and nearby residents heard loud thunder which they described as being "extremely violent."



Map 2. Two (2) of the lightning strikes reported by Vaisala between 5:00 AM and 7:00 AM EST on January 2, 2006 within a 5- mile radius of the top end of Sago Mine. The closest strike to the mine was also the strongest (101,000 amperes).

[3] Except for damage to the 12kV powerline, as noted and described in Section 5.5-3d.

On January 5, 2006, the OMHS&T ordered a report of lightning strikes in the Sago area at about the time of the explosion from Vaisala-Thunderstorm[4] in Tucson, Arizona Vaisala provided strike locations in latitude and longitude coordinates, together with estimates of the peak current in the discharges and the polarity (see **Appendix 5.5-2**: *STRIKEnet Report LA105304).*

Two large and nearly simultaneous positive cloud-to-ground strokes were recorded within 2 – 2.5 miles of the Omega seals across Old Second Left Section at the time of the explosion. One strike was located approximately 1 mile NW of the mine portal and the other approximately 1 mile to the SW.

Testimony by mine personnel on the surface described the wind picking up and a strong lightning flash illuminating the general area accompanied by ground shaking near the time of the explosion. Immediately afterward alarms began to sound on the CO monitoring system on the #4 Belt near the mouth of 2 Left Section. The CO monitor located at the 2 Left Section Belt tailpiece lost communications within 14 seconds. The underground power tripped at a splitter box near the #2 Belt Power Center within 23 seconds of the initial CO monitor alarm at #57 block on #4 Belt sounded. Later corroborating evidence included:

- Precise time correlation of the CO alarms with the lightning strikes
- Correlations with a subtle seismic event recorded by a seismograph in Morgantown, West Virginia
- Physical evidence at one of the lightning strike locations
- The accounts of nearby residents

How lightning actually entered the mine has been the subject of intense examination. The actual means by which this happened has at this writing not been determined with certainty. Additional research continues and resources are being used to gain more answers to this question than currently are available.

More details on the apparent linkage of lightning to the explosion are given **Section 5.5-2** of this report.

[4] Vaisala (pronounced *Vi' sa-la'*) is an Arizona-based commercial lightning service that provides reports of lightning strikes detected by the National Lightning Detection Network

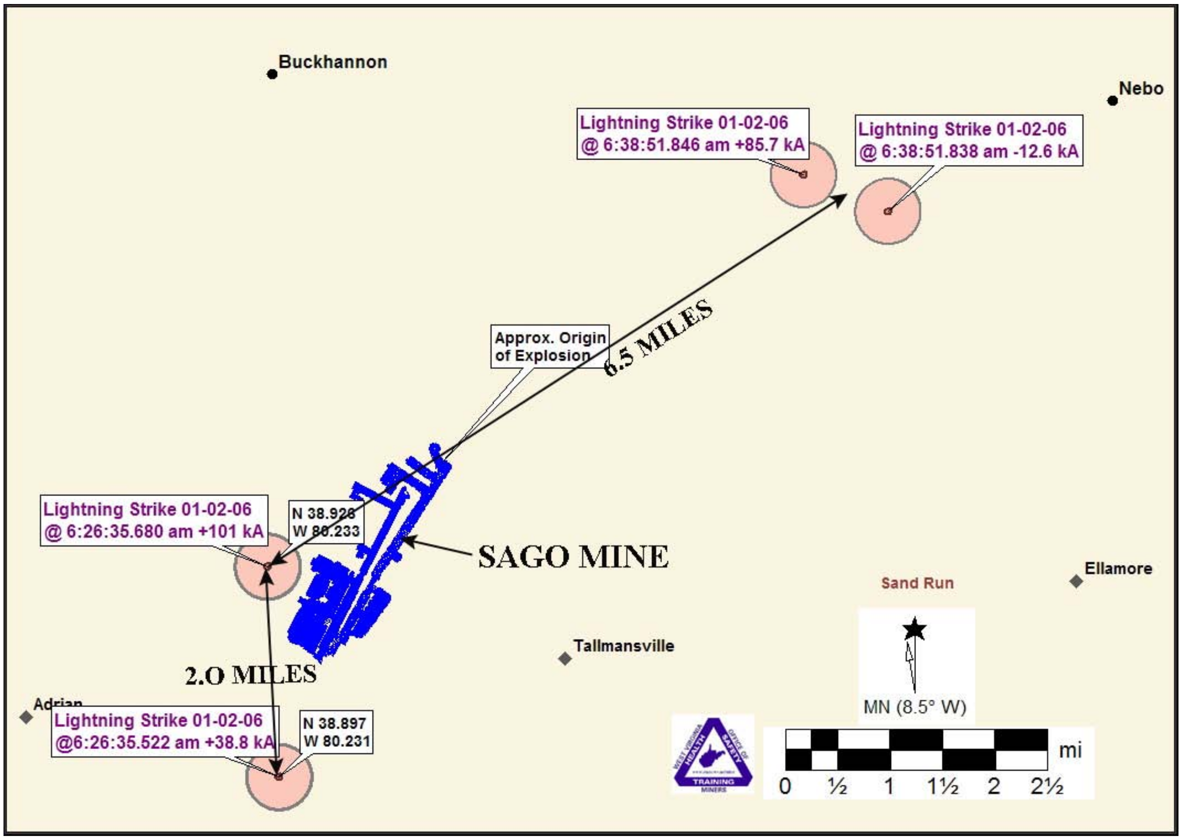
5.5-2 Lightning: Linkage to the explosion

5.5-2a Lightning Strikes recorded by Vaisala

Evidence for a lightning-related cause for the January 2, 2006 explosion began to emerge early in the investigation. There were reports of a severe strike close to the Sago Mine just prior to the belt alarms going off and the loss of power systems underground. As investigators waited for mine recovery efforts to allow the underground examinations to begin, the initial focus of the investigation began with the exploration of leads and collection of evidence which could be performed on the surface. Because of the strong electrical storms that were ongoing that day, the issue of lightning was addressed.

Several commercial lightning detection networks provide lightning data for almost any location in the country and requests for reports of these events can be made online. On January 5, 2006 OMHS&T obtained a report of four (4) lightning strikes within a 5-mile radius of a point on a map centered at the Old 2nd Left section of Sago Mine (**Appendix 5.5-2:** *STRIKEnet Report LA105304*) for the time period between 5:00 AM and 7:00 AM EST on 1-2-06. This report was provided by StrikeNet, a division of Vaisala, based in Tucson, Arizona. A summary of the results are shown below.

Date / Time	Latitude	Longitude	Amperes (000's)
01/02/06 06:26:35.522 EST	38.897	-80.231	+38.8
01/02/06 06:26:35.680 EST	38.926	-80.233	+101.0
01/02/06 06:38:51.838 EST	38.975	-80.123	-12.6
01/02/06 06:38:51.846 EST	38.980	-80.138	+85.7



Map 1. Location of lightning strikes within a 5 mile radius of the center of the Sago Old 2nd Left sealed area between the hours of 5:00 AM and 7:00 AM on the morning of January 2, 2006. Strike coordinates, magnitudes, and polarities were provided by Vaisala-Thunderstorm Unit in Tuscon, Arizona-- owned and operated by the National Lightning Detection Network (NLDN).

5.5-2b Physical evidence of lightning

On Friday, January 6, 2006 a representative of OMHS&T accompanied by an engineer from Anker Mining West Virginia Mining Company, Inc.[1] traveled to the closest (and strongest) of the reported lightning strikes using a GPS unit and the coordinates provided by Vaisala—a drive of approximately three minutes from Sago Mine. There, a large poplar tree was spotted with conspicuously fresh damage in its top. Closer inspection confirmed it to be the result of a very recent lightning strike. A wide gash extending from the top to the bottom of the 50-ft. tree spiraled 360-degrees (**Photo 1**). The force of the lightning produced a small gouge in the ground at the base of the tree. The poplar tree is located approximately 197 ft. from the coordinates provided by Vaisala.

[1] Anker Mining, WV provided GPS tracking and coordination with landowners

Wood debris from the lightning strike was found around the tree and this was documented in a survey performed on January 13, 2006 by Allegheny Surveys, Inc., based out of Birch River, WV[2] (see **Appendix 5.5-2**: *Forensic Survey of Poplar Tree*). Disintegration of the top portion of the tree left splintered wood fragments ranging from several feet to just inches in length, scattered symmetrically within a radius of approximately 150-feet.

Photo 1. A poplar tree recently stuck by lightning was located on 1-6-06 near the location where Vaisala recorded a +101kA lightning strike on 1-2-06 at 6:26:35AM. Photo by Kermit Melvin

On the afternoon of January 6, 2006 an attempt was made to locate similar physical evidence at each of the other three (3) locations. A +38.8 kA stroke that was approximately simultaneous with the poplar tree strike was reported approximately two (2) miles to the south. The other two strikes were both time-wise and geographically next to one another and located approximately six and one-half (6.5) miles to the northeast (see **Map 1**). The two lightning

[2] Allegheny Surveys. Inc. also assisted in establishing ground control to site the boreholes the night of January 2, 2006.

strikes to the northeast occurred 12 minutes and 16 seconds after the +101 kA and +38.8 kA strokes. Despite efforts on this day and on subsequent days, and despite repeat efforts by others, no other physical evidence of lightning from that day has been found at these remaining locations.

5.5-2c CO Monitor Correlation

The underground belt conveyor haulage system at Sago Mine is equipped with a Pyott Boone Model 1703 gas monitoring system (**Photo 2**) which continuously monitors carbon monoxide (CO) concentrations at strategic locations along its length. This information is analyzed and recorded on a desktop computer located at the mine dispatcher's office at the surface. A computer log for the period December 25, 2005 to January 11, 2006 is contained in **Appendix 5.5-2:** *Pyott Boone Data*.

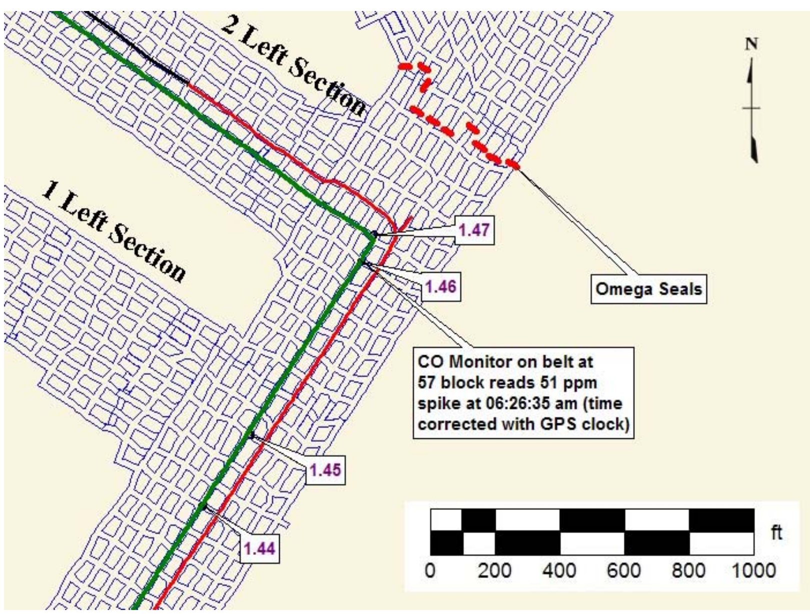
Photo 2. An example of the CO (carbon monoxide) monitors used to monitor the conveyor belt for mine gases underground at the Sago mine.

Map 2 (below) shows the location underground of CO monitors 1.46 and 1.47 on #4 Belt at or near where it adjoins #6 Belt. Unit 1.46 was located at #57 Break on #4 Belt—a distance of approximately 500 ft. from the front of the Omega seals and in-line with the explosion forces. The system is set up to signal trouble as follows:

CO Concentration	Status
< 5 ppm	Normal
5 ppm	Warning
10 ppm	Alarm
107 ppm	Max reading (sensor overload)

According to the computer log at 31 seconds after 6:31 AM sensor unit 1.46 on #4 Belt sent an alarm for 51 ppm[3] CO concentrations, and it was never heard from again. Seconds later the two monitoring units downstream on #4 Belt reported 107 ppm just before they too disappeared from the system. CO monitors and belt systems suddenly began reporting trouble, reporting CO, power loss, and dead communications along #4 Belt and also along # 5 Belt and #6 Belt[4]. These events document the timing of the explosion which, according to the computer clock apparently began with the 51 ppm alarm at 6:31:31 AM.

The Pyott Boone CO monitoring system sends its information to the surface through a communication line to a standard PC desktop computer running Windows 2000. The time assigned to recorded events is based on the time kept by the internal clock in the computer, which was set close to the correct time, but not exactly.



Map 2. Location of some of the CO monitors on the mine conveyor belt at the time of the explosion.

[3] ppm-- parts per million
[4] located in 1 Left Section and 2 Left Section, respectively

On January 11, 2006 an accuracy check was performed on the computer clock and it was found to have been set 4 minutes and 56 seconds ahead of the actual time[5]. This determination was made by comparing the time that had been set manually with a GPS receiver that reported Universal Time[6] -- the same time that Vaisala and other lightning detection networks use to report lightning strikes.

After correcting the log of the CO monitor by subtracting 4 minutes and 56 seconds from the recorded times the actual time of the 51 ppm CO alarm at 6:31:31 AM was determined to be 6:26:35 AM. This is only a few fractions of a second different from the time of the +101 kA and +38.8 kA lightning strikes that were recorded by Vaisala: 6:26.35.680 AM and 6:26:35.522 AM, respectively. The estimated accuracy of this time correlation is +/- 1 second. A compelling connection with lightning was thus established.

5.5-2d Seismic event correlation

The timing of the explosion as indicated by the CO monitor log (using the corrected time) has been corroborated by at least four (4) seismographs in West Virginia and Virginia that recorded a subtle ground disturbance very close to Sago Mine at that time. The location of the epicenter of this subtle seismic event is in the region of Sago Mine.

Seismographs residing at the West Virginia Geological Survey located near Mont Chateau, and at least three (3) other locations recorded a subtle seismic event that was analyzed by a seismologist[7] at Virginia Polytechnic Institute in Blacksburg, Virginia. Seismograph recordings from stations located in Blacksburg, Virginia; Prospectville, Virginia; and Forest Hill, West Virginia were also used. The Sago seismic event correlated closely with the (corrected) timing of the Sago mine explosion as signaled by the 51 ppm CO spike on the Pyott Boone computer log. A brief report was written about the analysis of the seismic data and provided to investigators. A copy of this report is given in **Appendix 5.5-2**: *Results from Analysis of Seismic*

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[5] Memorandum to Doug Conaway from Monte Hieb dated January 12, 2006 (see **Appendix 5.5-2**)
[6] Time correlation provided by Allegheny Land Surveying and documented later in a letter dated January 14, 2006 (see **Appendix 5.5-2:** *Time Differential of CO Monitors computer at Sago*)
[7] Martin Chapman, Director, Department of Geosciences, VPI&SU; Results from the Analysis of Seismic Data for the January 2, 2006 event near Sago, WV, 8pp.

Data for the January 2, 2006 event near Sago, WV. Three (3) different methods were used to calculate the timing[8] of the seismic event.

Method 1:	Depth constrained	06:26 AM 36.6 sec. to 06:26 am 39.9 sec.
Method 2:	Depth unconstrained	06:26 AM 35.4 sec. to 06:26 am 41.2 sec.
Method 3:	Depth and loc. unconstrained	06:26 AM 36.5 sec. to 06:26 am 40.0 sec.
	Average:	06:26 AM 38.2 seconds +/- 2 seconds.

The report concludes that it is possible the exact time of the event could be a bit earlier due to the fact that the signal was so close to the noise level that the exact arrival times of the P-wave (the "primary" or "compression" wave) and the S-wave (the "secondary" or "shear" wave) are not precise.

Summary and conclusions:

The very close time correlation of two near-simultaneous lightning strikes with the first signals from the CO monitor indicating that there had been an explosion, together with corroboration of the time by analysis of a subtle seismic that originated near Sago Mine, provides strong circumstantial evidence that has led investigators to conclude that lightning was associated with the mine explosion of January 2, 2006, and most probably was the direct cause.

• Time of +38.8 kA lightning strike	6:26 AM 35.522 sec. +/- .0005 sec.
• Time of +101 kA lightning strike	6:26 AM 35.680 sec. +/- .0005 sec
• 51 ppm CO spike (first detection of explosion)	6:26 AM 35 sec. +/- 1 sec.
• Seismic event recorded by MCWV, et.al.	6:26 AM 38.2 sec. +/- 2sec.

8 Seismographs are also based on GPS clock time

5.5-2e Residents interviews

Information provided by lightning detection networks gives only part of the story about the lightning activity in the Tallmansville Road area above Sago Mine that morning. Residents' descriptions about what they saw and felt that morning provides an account of the electrical storms that is not recorded elsewhere. Although this testimony varies, there is a sense that the storm was remarkable in several ways:

- There was considerable lightning and thunder that morning, but one particular discharge stood out from the rest.
- That flash was accompanied by what many describe as an explosion or long crash that shook the ground.
- The ground shaking was described primarily by people living on the ridge above the Sago Mine. Shaking on Bailey Ridge[9] was described as exceptionally strong, lasting for many seconds.
- While hardly anyone describes a lightning bolt striking the ridge, many describe a flash that momentarily lit up the sky like day. Some describe a strong flash to the east—one so strong it left one resident's ears ringing.
- Rolling thunder following the flash was described by some. One resident on Bailey Ridge described it as rolling from east to west.
- Remarkably, no one lost power that morning. Lights may have flickered, but if there were outages due to lightning, they were few in number.

It is unlikely that the explosion caused the ground shaking that residents on the ridge describe. The men at 1 Left Switch did not hear an explosion. They felt the blast and were pelted with debris, but did not hear an explosion. Strong ground shaking was not mentioned.

Residents that live between the location of the +101 kA lightning strike and the vicinity of the communication towers to the northeast on Bailey Ridge were interviewed and summaries of those interviews are given below. Also, **Appendix: 5.5-2:** *Sago Mine Resident Interviews* gives a map showing the locations of those interviewed and selected comments of the residents.

9 A high ridge situated approximately one (1) mile east of the area where the underground methane explosion occurred.

3-8-06 Resident 1

Residence on the surface above Old 2nd Left Section

This resident was up at 4:00AM on January 2, 2006 (normal waking time). Thunder and lightning were occurring in the area for most of the morning. He could not be specific on the location or distance away. There were no electrical power or telephone interruptions.

- Lightning was identified in the area. Recalls lightning from 5:00 AM to late morning.
- Thunder was identified in the area but no relation to timing with lightning strikes.
- Proximity of lightning not distinguished.
- No ground strikes noted.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-14-06 Resident 2

Plant manager for the potable water for the area south of Buckhannon River.

This water supply system provides mine supply water and potable water for Sago Mine. The treatment plant is near the second Vaisala, lightning strike location. Plans and drawings indicate that the line construction to the mine is PVC – not - metal pipe. The only exception is 140 ft. of metal pipe crossing the Buckhannon River. The potable water supply line is 4 in. and the mine water supply line is 6 in. Lab analysis shows that the specific conductance of both samples are 110.

3-15-06 Resident 3

Residence above explosion area of Sago.

This resident's house sets directly over the sealed area of Sago Mine (between 7 & 8 entry – next to the last cross cut of mains). Between 6:00 and 6:30 AM he was awakened by the storm. Lightning in the area illuminated the sky and the sound of thunder was instantaneous with the lightning. It was so violent that it shook the windows and pictures in the house. Everything outside was as bright as mid day when the lightning would strike. He was at the doorway on the east side of the house trying to retrieve his pets. Did not specifically see lightning – only the illumination. When it thundered, the cats in the house scattered-- the fur raised on the animals. When asked about the electrical power and telephone, he stated there were no disruptions, but thunderstorms usually knock the power out.

- Lightning was identified in the area and was very strong. Timing of lightning was between 6:00 and 6:30AM.
- Thunder was identified in the area and was intense.
- Proximity of lightning was very close (flash-boom).
- No ground strikes physically observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-16-06 Resident 4

Resident above explosion area of Sago

This resident was awaken approximately 5:00AM from the lightning and thunder, she checked on the children sleeping over with her daughter. She stated, clearly lightning and thunder was in the area. Did not know the location of the lightning, but it illuminated the house when she checked the time. She went back to bed and at 6:30 AM she was awakened by thunder / explosion. This was so extreme that it frightened her. It shook the pictures on the wall. She feels it was the explosion and not thunder. She stated that there was no electrical power and, to her knowledge, telephone loss, which seemed unusual to her because electrical storms usually disrupt the power in the area.

- Lightning was identified in the area and was very strong.

- Thunder was identified in the area and was intense. Was awakened by thunder at 6:30 AM.
- Proximity of lightning was close.
- No ground strikes observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-20-06 Resident 5

Resident above explosion area of Sago

This resident is elderly and her house is on the southern edge of "Old 2nd Left Section", 3 breaks inby the mains. She was up around 6:00 AM and did not see any lightning or hear thunder. She did hear a BOOM around 6:30 AM and feels it was the explosion. She stated that she doesn't believe that lightning caused the Sago explosion. There were no power problems – not even flickering, which usually happens when a storm is in the area. To her recall, the telephone service was not interrupted. She stated there are two wells and one cistern on her property. On April 19th samples and location of two wells and two springs were taken. These water sources were sampled and sent to a laboratory for analysis.

- Lightning was not identified in the area.
- Thunder was not identified in the area, but did hear a boom (She feels it was an explosion.).
- Proximity of lightning was not identified.
- No ground strikes observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-22-06 Resident 6

Resident above explosion area of Sago

This resident was up at 4:30 AM and her husband left for work at 5:15 AM. There was a storm in the area (bushes along house were blown by wind / rubbing house). Did not hear any thunder or see lightning. Between 5:45 & 6:30 AM she was awakened by a loud noise that seemed to come from the ground. She thought it was an earthquake and ran to the bathroom for protection. The noise also woke the children. There was no power outage and to her knowledge the telephones were okay.

- Lightning was not physically identified in the area.
- Thunder was not identified in the area (Thought loud noise came from the ground and felt it was an earthquake. Timing was between 5:45 and 6:30 AM).
- Proximity of lightning was not identified.
- No ground strikes observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-28-06 Resident 7

This resident was awake at 5:00 AM. There was a storm in the area with thunder and lightning. Around 6:30 AM a strike of lightning was so strong he actually thought a bomb went off. There was no loss of power, and between 10:00 to 10:30 he used his telephone.

- Strong lightning was identified in the area and, the time was around 6:30 AM.
- Thunder was identified in the area and intense.
- Proximity of lightning was very close, but not measurable.
- No ground strikes were observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-28-06 Resident 8

This resident was awake at approximately 6:00 AM. Stated the thunder was different and rumbled for a long time. There was no power interruption, and, as far as she knows, no problem with the telephone. She did not use the telephone until the afternoon that day.

- Lightning was identified in the area, but not severe.
- Thunder was identified in the area, but seemed normal.
- Proximity of lightning was not identified.
- No ground strikes were observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-30-06 Resident 9

This resident was up around 6:00 AM. A storm was in the area around 6:30 AM. The thunder was the strongest he had ever heard. There was an instant "flash – boom". The power flickered but stayed on. The telephone service, to his knowledge, also stayed on.

- Lightning was identified in the area and very strong. The time was identified around 6:30 AM.
- Intense thunder was identified in the area.
- Proximity of lightning was very close (flash-boom). (Location was to the south of his home.)
- No ground strikes were specifically located.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

3-30-06 Resident 10

This resident let her pet dog out of the house around 6:00 AM. She stated the storm was very bad with multiple strikes of lightning – mostly to the northeast of their home. The electricity and telephone service never did go out.

- Strong lightning was identified in the area. The storm occurred all morning, but was the strongest around 6:30 AM.
- Intense thunder was identified in the area.
- Proximity of lightning was not identifiable.
- No ground strikes were observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

4-3-06 Resident 11

This resident stated he was awakened at 6:30 AM by the loudest thunder he had ever heard. He could not identify the location or direction of the lightning. There were multiple lightning strikes in the area. He had no telephone or electricity outage.

- Lightning was identified in the area and woke him around 6:30 AM.
- Intense thunder was identified in the area.
- Proximity of lightning was not notable.
- No ground strikes were observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

4-3-06 Resident 12 & 13

The two stated that they were awakened by thunder around 6:30 AM. The thunder and lightning were fairly strong, but they never noticed any specific direction. They had no telephone and electricity outage.

- Fairly strong lightning was identified in the area. Woke him around 6:30 AM.
- Intense thunder was identified in the area.
- Proximity of lightning was not notable.
- No ground strikes were observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

4-3-06 Resident 14

This resident stated there was very severe lightning to the south of his residence. The storm around his house was not as severe. He stated that there was definitely lightning in the area, but he could not be specific on the location of any strikes. His wife is very afraid of lightning, and the two spent the morning in their basement. Both the telephone and electricity stayed on that day.

- Very strong lightning was identified in the area to the south, but was not as strong around the house. No specific time was identified.
- Thunder was identified in the area.
- Proximity of lightning was widely dispersed.
- No ground strikes were observed.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

4-3-06 Resident 15

The storm was fairly strong with lightning and thunder. He did not notice any specifics on the location of the lightning.

- Lightning was identified in the area.

- Thunder was identified in the area.
- Proximity of lightning was dispersed.
- No ground strikes were observed.
- Electrical service was not noted.
- Telephone service was not noted.

4-3-06 Resident 16

The lightning and thunder were very strong. Shortly after 6:00 AM the thunder occured almost immediately after the lightning strikes. One very strong lightning strike was directly in front of his house (east of his house). This strike made the sharpest thunder of all, and the resonance actually caused his ears to ring. He feels that this was the strongest lightning he had ever seen. He had no power or telephone outage, but thinks the lights did flicker on occasions.

- Lightning was identified in the area. It was very strong and close.
- Intense thunder was identified in the area. The strongest thunder was shortly after 6:00 AM.
- Proximity of lightning was very close and to the east.
- No ground strikes were observed.
- Electrical service was not interrupted but flickered a little.
- Telephone service was not interrupted.

4-19-06 Resident 17

Resident 17 was up early that morning. Lightning with instant thunder occurred just before 6:30 AM. The thunder was long lasting with a rumble of several seconds. The electrical and telephone service stayed on.

- Lightning was identified in the area around 6:30 AM. It was very strong and close.
- Thunder occurred instantly after lightning strikes.

- Electrical service was not interrupted.
- Telephone service was not interrupted.

4-19-06 Resident 18

This resident and family were up early. The thunder was very strong and occurred shortly after 6:00 AM. The lightning was primarily to the southwest. They said it actually sounded like two strikes two to three minutes apart. They had no electrical or telephone interruptions.

- Lightning was identified in the area shortly after 6:00 AM. It was very strong and close.
- Thunder was strongest to the southwest and sounded like two reports of thunder.
- Electrical service was not interrupted.
- Telephone service was not interrupted.

11-22-06 Resident 19

These residents describe a very bright flash sometime after 6:00 am that lit up everything like daylight on both sides of the house. The thunder rolled from east to west. The husband who describes himself as a sound sleeper was awakened by a huge shudder of thunder. It was compared to the sound of a train going over a trestle. And again, "It was just rolling-- like an airplane crash that just keeps going." The jolt shook the house so badly the house was shuddering as he arose and pulled on his trousers, and he describes continued shaking after he walked over to the living room. He checked his foundation for damage. "It just felt strange."

5.5-2f Examination of Data from Lightning Detection Networks

Introduction

The U.S. National Lightning Detection Network (NLDN) detected a large, 2-stroke, positive cloud-to-ground lightning flash in the region of the Sago mine on the morning of January 2, 2006. At about the same time, a methane explosion occurred in a sealed area of the mine. In this report, we will first summarize the lightning information that was obtained by the NLDN, and then we will examine the data that were obtained by three other lightning detection networks. We will discuss the possibility of upward or "triggered" lightning in the region of the Sago mine that may not have been reported by the NLDN or the other networks.

NLDN Data

The NLDN contains about 200 gated, wideband lightning sensors that cover the U.S. and Canada, and it is owned and operated by the Vaisala-Thunderstorm Unit in Tucson, AZ. The sensors are precisely time-synchronized using GPS receivers, and the NLDN computes the locations and amplitudes of the coincident electromagnetic signals using an optimum combination of the times-of-arrival, magnetic directions, and source amplitudes of all pulses that are characteristic of cloud-to-ground lightning strokes.

On the morning of January 2, 2006, the NLDN detected 69 CG strokes within 30 km of the mine entrance in the interval from 06:00 to 06:30 EST. A map showing the locations of these strokes is given in **Figure 1**, and a detailed listing of the stroke parameters is given in **Appendix 5.5-2**: *Attachment A*. It should be noted that the NLDN reported two, large positive events within 6 km of the mine at about the time of the explosion. The times of the first and second strokes were 11:26:35.523 UT (06:26:35.523 EST) and 11:26:35.680 UT (06:26:35.680 EST), respectively, and the interval between them was 157 milliseconds. The first stroke had an estimated peak current (Ip) of about +39 kiloamperes (kA), and the second had an Ip of +101 kA. A map showing the locations of all strokes that occurred in the 4-hour interval from 04:30 to 8:30 AM EST within 5 miles of the mine entrance is given in **Figure 2**, and the locations of all strokes detected in the 2-hour interval from 05:00 to 07:00 EST within 5 miles of the point-of-origin of the methane explosion is given in **Figure 3**. The elliptical regions shown in red around the stroke locations in **Figures 1, 2**, and **3** are the boundaries of the 99% confidence regions[10].

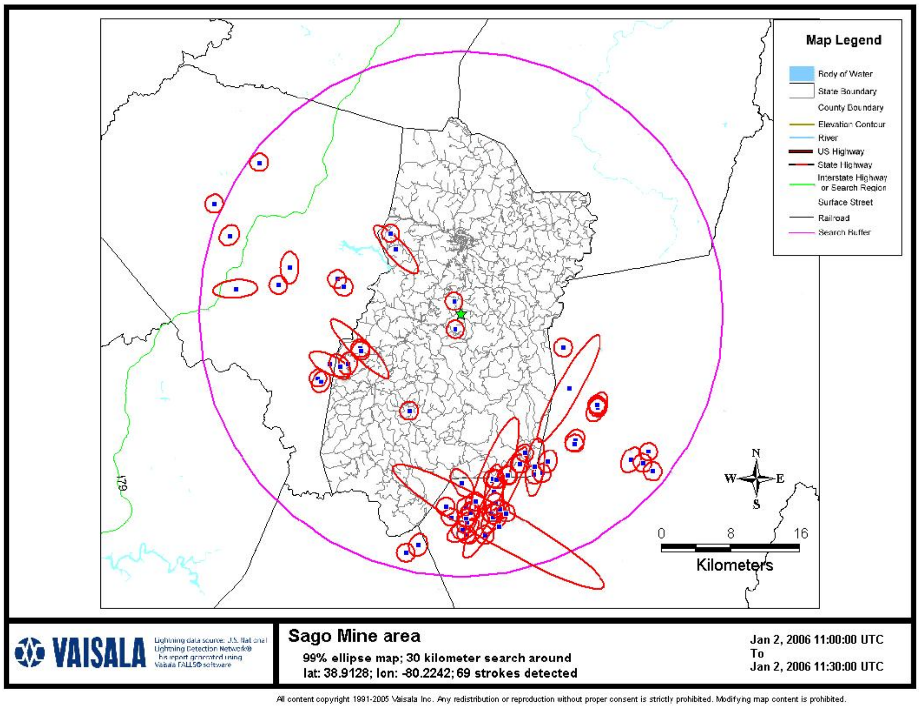


Figure 1. Cloud-to-ground lightning strokes detected by the NLDN within 30 km of the entrance to the Sago mine between 06:00 AM and 06:30 AM EST on January 2, 2006. The red circles and ellipses show the boundaries of the 99% confidence regions.

[10] Cummins, K. L., M. J. Murphy, E. A. Bardo, W. L. Hiscox, R. B. Pyle, and A. E. Pifer (1998), A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network, *J. Geophys. Res., 103,* 9038-9044, 1998a

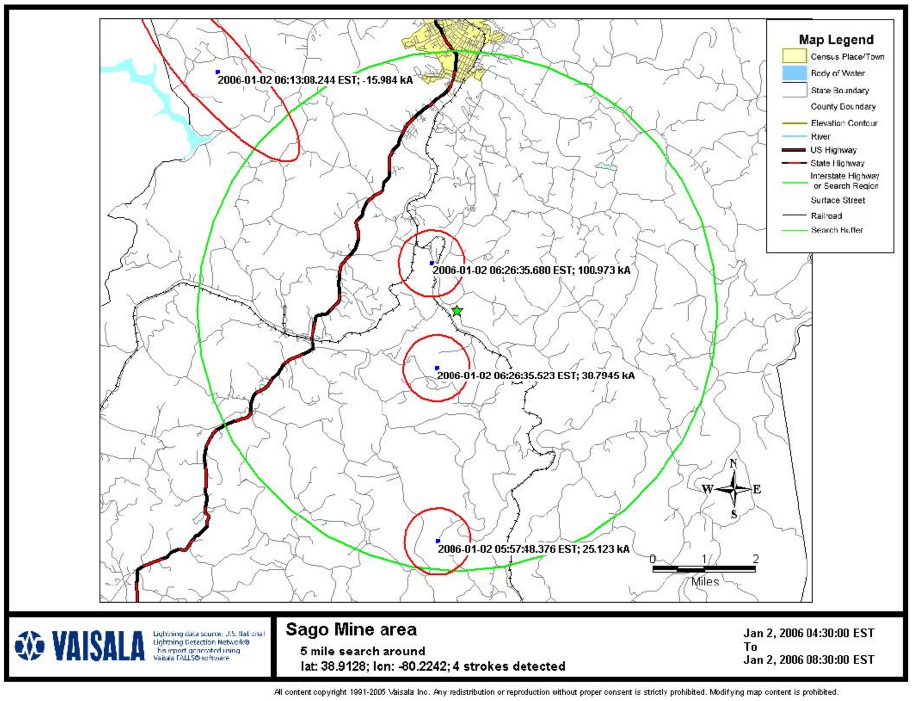


Figure 2. Cloud-to-ground lightning located within 5 miles of the entrance to the Sago mine between 04:30 AM and 08:30 AM EST on January 2, 2006.

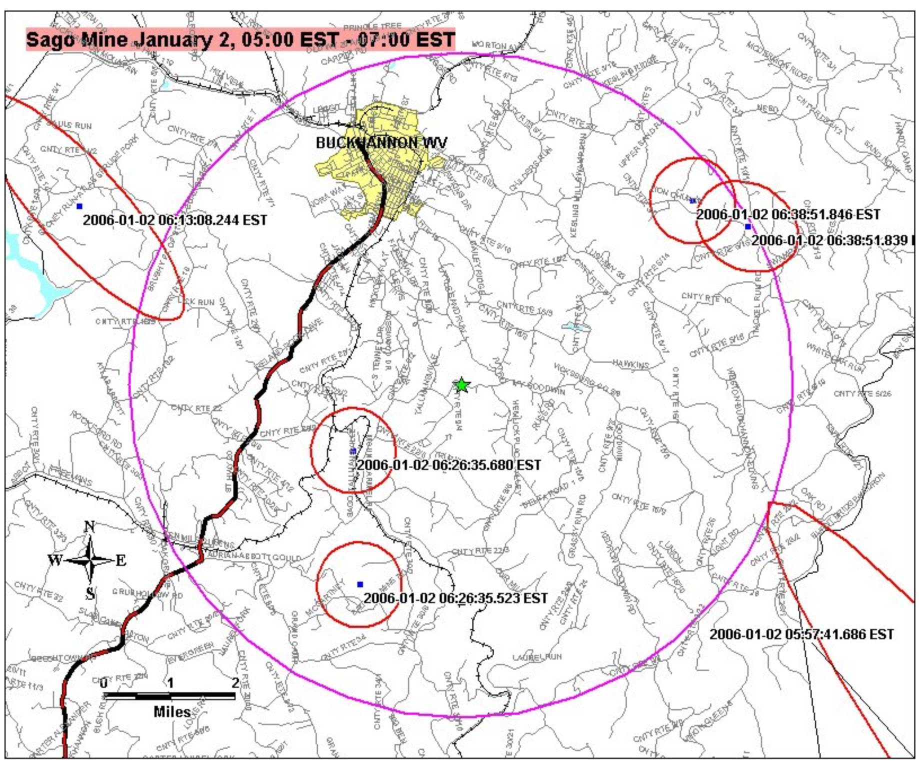


Figure 3. Cloud-to-ground lightning located within 5 miles of the point-of-origin of the explosion at the Sago mine between the hours of 05:00 AM and 07:00 AM EST on January 2, 2006.

NLDN Location Accuracy

A Vaisala Report dated January 26, 2006, summarizes the parameters of the two strokes that were detected near the Sago mine on January 2 (see **Appendix 5.5-2:** *Attachment B*). The second stroke at 06:26:35.680 EST had an estimated peak current of +101 kA and was located about 3 km (1.9 mi) from the point-of-origin of the explosion. A lightning struck tree was found within 200 feet of this location shortly after the explosion (see **Photo 1**), and the presence of this tree shows that the NLDN location accuracy was quite good in the region of the Sago mine (see also **Appendix 5.5-2**: *Attachment C*).

An evaluation of the overall NLDN detection efficiency and other performance parameters on January 2, 2006, is given in **Appendix 5.5-2:** *Attachment D.*

Lightning Detected by the USPLN

The United States Precision Lightning Network (USPLN) detected lightning in the region of the Sago mine near the time of the explosion, and a complete report summarizing the USPLN measurements is given in **Appendix 5.5-2:** *Attachment E*. The salient information on the two strokes that were located is given in Appendix 1 (below). It should be noted that the strike at 06:26:35 EST was undoubtedly the same as the first NLDN stroke, and the peak amplitudes of both were similar, +35 kA in the USPLN report and +39 KA in the NLDN dataset. The USPLN did not report the +101 kA stroke at 06:26:35.680 EST.

Appendix 1. Cloud-to-ground lightning strikes for the period of 5:00 AM EST January 2, 2006 to 7:00 AM EST January 2, 2006 within the 10 mile view shown above. Time is in 24-hour Eastern Standard Time (EST) format. Heading is relative to due north from the location of interest. For example, 90 degrees = east, 180 degrees = south, 270 degrees = west, 0 degrees = north. (Lightning data source: USPLN)

Date (mm/dd/yy)	Time (hhmmss)	Latitude (Degrees)	Longitude (Degrees)	Magnitude (Amps)	Heading (Degrees)	Range (Miles)
01/02/06	62635	38.907	-80.221	35000	203	2.5
01/02/06	63851	39.007	-80.288	-35800	315	6.5

Lightning Detected by the WWLLN

The World Wide Lightning Location Network (WWLLN)[11] detected a lightning discharge in the region of the Sago mine at the same time as the first NLDN stroke, and Prof. Robert Holzworth at the University of Washington kindly provided the following event parameters:

Year	Mo	Day	Hr	Min	Sec	.fract	Lat	Long	el	#sta (UTC or Z)
2006	1	2	11	26	35	.522888	38.85	-80.21	3	5

The uncertainty in time was about 3 microseconds, and this report is clearly the same (first) stroke that was detected by the NLDN and the USPLN. The WWLLN did not report the +101 kA stroke at 06:26:35.680 EST.

Lightning Waveforms Recorded by the LASA

The Los Alamos Sferics Array (LASA)[12],[13] recorded broadband lightning waveforms at 3 sensor sites on January 2, 2006, at times that were consistent with the first and second strokes detected by the NLDN, after the times for electromagnetic propagation were subtracted from the times that the signals were received. **Figures 4, 5**, and **6** (courtesy of Dr. X-M Shao) show the electric field waveforms recorded at Daytona Beach, FL; Lincoln, NE; and Garden City, KS, respectively, at the times of the first (top) and second (bottom) NLDN strokes near the Sago mine. Note in **Figures 4 to 6** that all pulses begin with a positive excursion that is characteristic of a positive lightning impulse propagating over the ground, and then there is a large, negative excursion that is caused by the first ionospheric reflection at the distances involved.

[11] Jacobson, A. R., R. Holzworth, J. Harlin, R. Dowden, and E. Lay, Performance Assessment of the World Wide Lightning Location Network (WWLLN), using the Los Alamos Sferics Array (LASA) as Ground Truth, *J. Atmos. Oceanic Tech*., *23*, 1082-1092, August 2006.

[12] Ibid.

[13] Shao, X-M, M. Stanley, A. Regan, J. Harlin, M. Pongratz, and M. Stock, Total Lightning Observations with the New and Improved Los Alamos Sferics Array (LASA), J. Atmos. Oceanic Tech., 23, 1273-1288, October 2006.

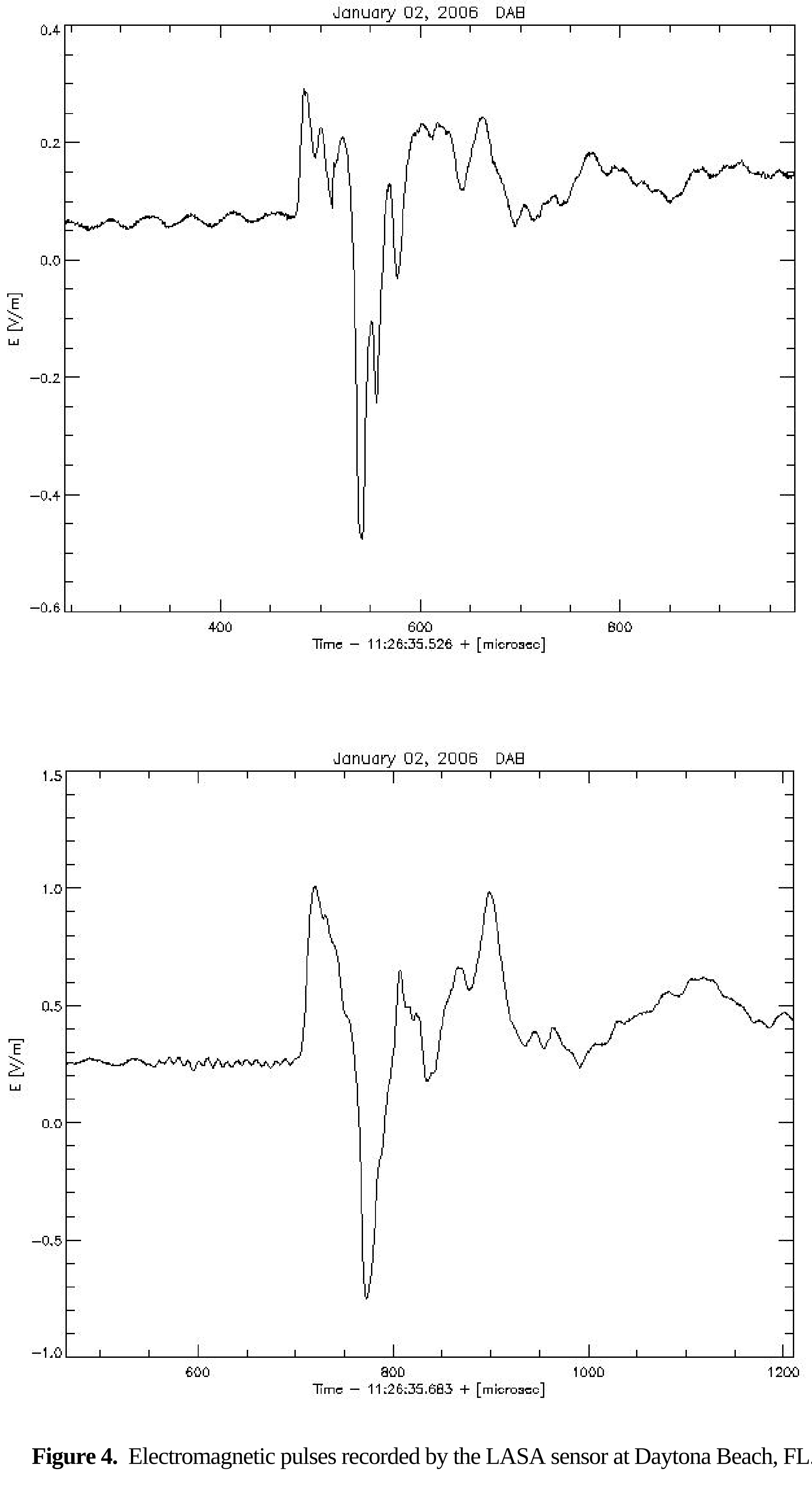
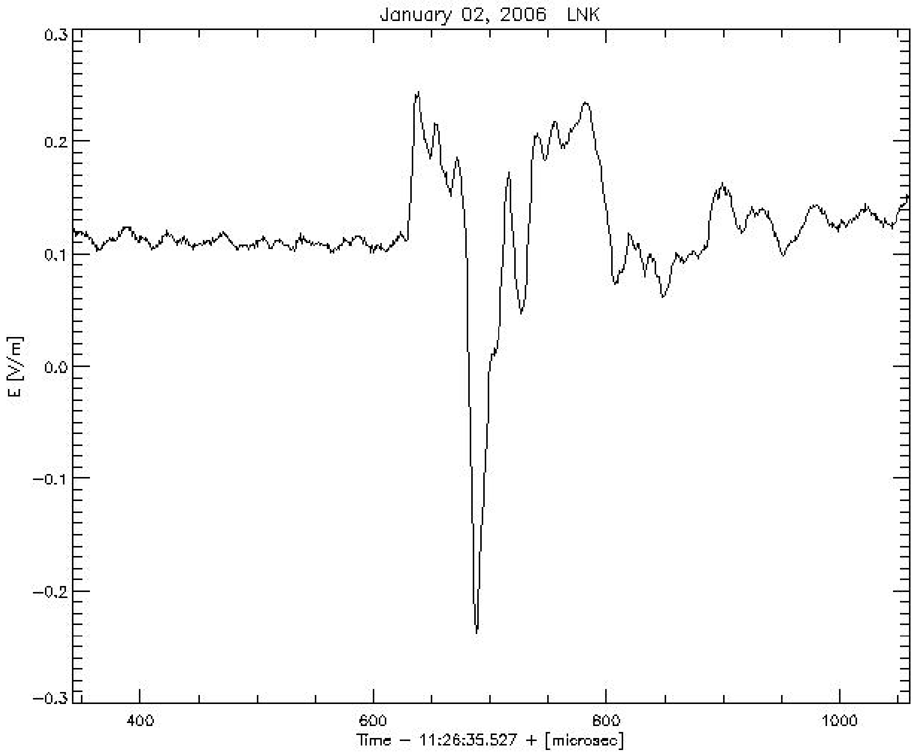


Figure 4. Electromagnetic pulses recorded by the LASA sensor at Daytona Beach, FL.



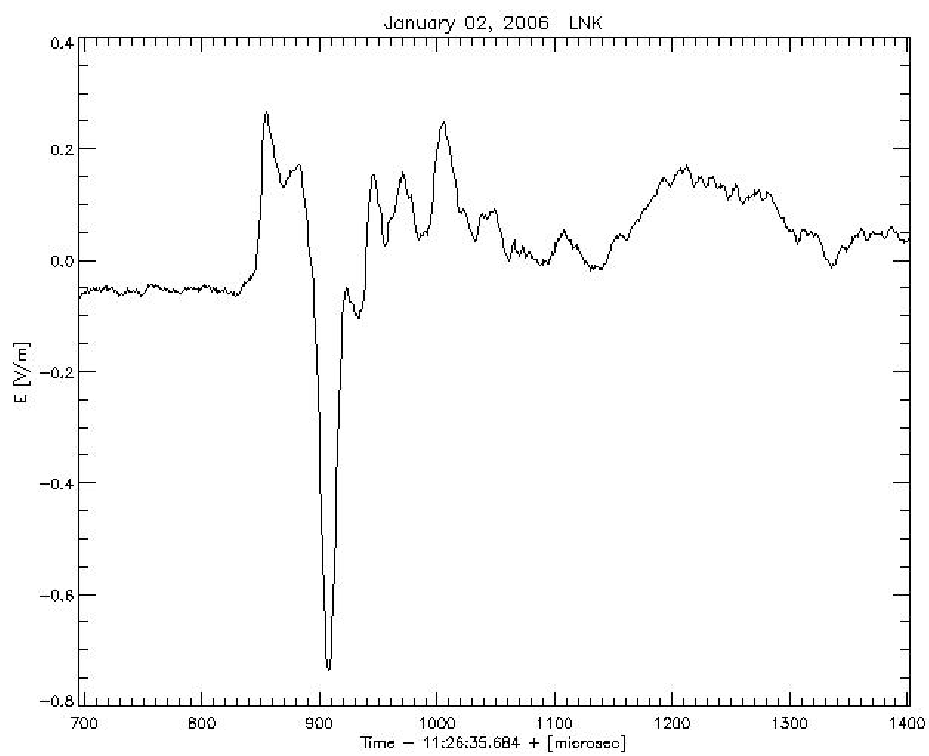


Figure 5. Electromagnetic pulses recorded by the LASA sensor at Lincoln, NE.

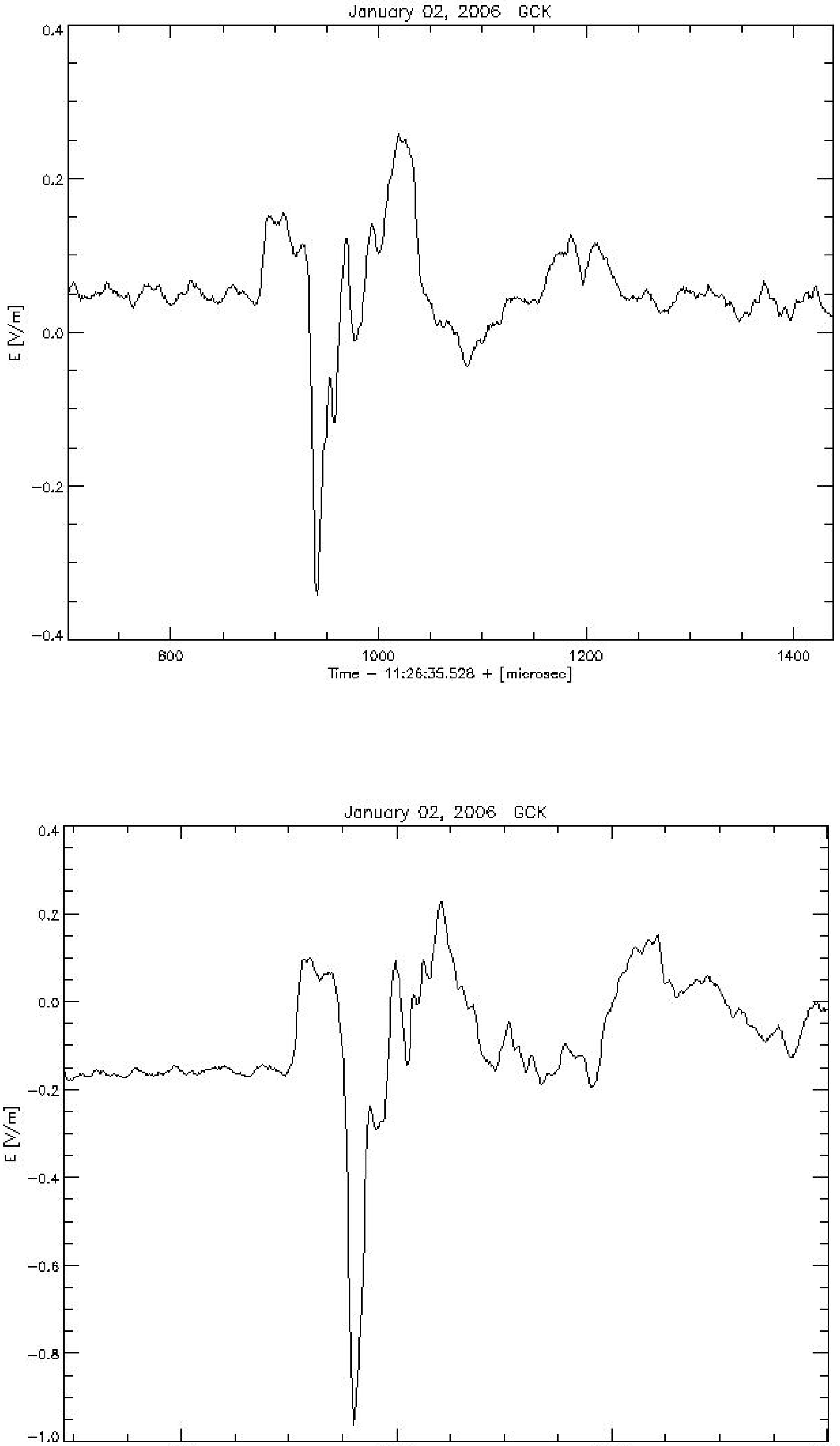


Figure 6. Electromagnetic pulses recorded by the LASA sensor at Garden City, KS.

Search for Missed Lightning Strokes

In an effort to find evidence of any small lightning strokes that may have been detected by individual sensors but not reported by the NLDN, we searched the NLDN database for all uncorrelated reports from individual sensors that were within 500 km of the Sago mine where the lightning direction-of-arrival was from the Sago mine at about the time of the explosion. The results are summarized in **Appendix 5.5-2:** *Attachment F*. The key point in Attachment F is that there is no evidence of any small ground strokes or cloud discharges in the region in a 10 second interval prior to the first positive stroke that was reported by the NLDN. The two small reports (highlighted in red) from the sensor at Spencer, WV, at 11:26:35.512345 UT and 11:26:35.518452 UT were undoubtedly due to cloud or leader pulses that preceded the first positive stroke at 06:26:35.523 EST (11:26:35.523 UT).

Summary and conclusions

Information from multiple time-synchronized sensors indicates that there were two (2) large cloud-to-ground lightning strikes near the Sago Mine at the same time that the mine explosion occurred. This information is regarded as strong circumstantial evidence contributing to the conclusion that lightning caused the January 2, 2006 mine explosion at the Sago Mine.

Residents confirm that there was electrical storm activity on the morning of January 2, 2006. Residents on Tallmansville Road reported a loud crash or explosion, followed by ground shaking. Several residents thought that this was the mine explosion. This is unlikely, however, as the crew of First Left Section who were approximately one-thousand (1000) feet from the explosion did not report hearing it, or feeling the earth shake,-- they felt only the wind and the effects of flying debris.

A review of the raw lightning data from the NLDN did not produce any other evidence of cloud-to-ground lightning strikes in the region of the Sago mine in the several seconds prior to the time of the explosion. The network is designed to detect and report cloud-to-ground discharges. However, strokes that have less than 3 kA peak current, cloud discharges, or upward lightning are not normally reported by the present lightning detection systems.

5.5-3 How lightning may have entered the mine

There are many possible pathways or mechanisms whereby the electromagnetic energy from lightning could have entered the Sago Mine, and which mechanisms were actually involved are still being studied. Before solutions and precautions can be developed to prevent future accidents like Sago it is first necessary to understand the possible modes by which lightning energy could have entered the mine.

5.5-3a Possible modes of entry

Lightning produces very large voltages and currents at the ground strike point and the resulting paths of current are often unpredictable and capricious in their behavior. The only thing we can say for sure is that if there is a direct transfer of electrical energy, the current will tend to follow the path of lowest impedance. But lightning can also create current and voltage surges in conductors that are in close proximity to the strike point without actually contacting them. At this time, investigators generally believe that there are at least three (3) ways the electrical energy from lightning can propagate into an underground mine and cause an explosion:

<u>Possible means by which lightning could enter the mine:</u>

1) **Electrical Conduction –**

   a) the lightning current can travel into mines on metallic conductors like the electric power wires, communication cables, the belt structure, deep well casings, rail, wire roof mesh, etc.

   b) lightning current can travel directly through the earth or be guided by low-resistivity layers and geological structures that trap water underground

2) **Magnetic Induction**—the large, time-varying magnetic field from lightning can cause electric current to flow in a wire loop, without actually touching it. If there is a gap in the loop, large voltages can appear across the gap.

3) **Electric Field Coupling** – if the skin depth of the overlayer is large, low frequency electromagnetic fields from lightning can propagate into the earth and cause transient voltages to appear on large conductors, like vertical gas wells or the metallic roof mesh.

Various networks of gas lines, utility lines, power lines, wire roof mesh (underground), and an abandoned pump cable (underground) were examined. Also, various methods of direct coupling through the earth were explored both analytically and through experimentation.

As of this writing, there is no clear proof of the precise mechanism by which the electricity from lightning entered the Sago mine. The body of evidence gathered during the investigation, however, allows the following points to be made with some degree of confidence.

- The timing of the two nearby lightning strikes at 6:26:35 AM EST coincides to within 1 second with the mine explosion [1] (see **Section 5.5-2**)
- There are no known continuous metallic conductors extending from the surface of the ground into the sealed area of the mine void at the time of the explosion—nor underground from the outby side of the seals to the inby side.[2]
- Each of the coupling scenarios that remain under consideration today involve transmission of lightning-related energy into the sealed area, ***at least in part***, through or along solid rock and/or fractured earth strata without the presence of a continuous metallic conductor to the surface

5.5-3b The possibility of Upward or Triggered Lightning

Upward or triggered lightning discharges are often initiated by tall structures when such a structure is in close proximity to natural lightning[3] This type of event is frequently missed by the NLDN[4]. either because there are no return strokes in the discharge or because the stroke waveforms do not

[1] Based on the 51 ppm CO spike at block 57 at 6:26:35 +/- 1 second.
[2] A steel sample tube approximately 40 feet long was installed as required in the Omega seal #10 (seal located farthest east) for purposes of sampling mine gases. It is equipped with a valve and installed near the roof. No wire roof mesh was used in this location.
[3] Rakov, V.A. and M.A. Uman, Lightning: Physics and effects, Cambridge University Press, 687 pp., 2003, Chapter 6.

have an amplitude or shape that corresponds to natural strokes. An example of a flash that was triggered by a radio tower in Rapid City, SD, is given in **Photo 1**. In this case, the discharge was also recorded by a video camera that had precise timing, and analysis showed that it occurred approximately 120 milliseconds ***after*** the NLDN located a positive ground stroke about 7 km (4.4 miles) from the tower.

Significantly, the upward flash in **Photo 1** was ***not reported*** by the NLDN, either because it did not contain return strokes, or if such strokes did occur, their peak currents were below the NLDN trigger detection threshold[5] and/or they had improper waveforms.

Upward lightning is also known to strike power lines, especially in the winter months, and an example of this phenomenon is shown in **Photo 2**. The exposure for the image in Photo 2 was ¼ second or 250 milliseconds.

Photo 1. An upward, ground-to-cloud lightning flash in Rapid City, SD, on 26 March 2004. [Photo © 2004 by Tom Warner]

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4 National Lightning Detection Network (Vaisala)
5 That threshold is reported by NLDN to be 3 to 5 kA.

The locations of tall towers in the region above the Sago mine, and that are located close to pipelines or other ground conductors, are shown on **Map 1**. The two positive cloud-to-ground strokes that were located by the NLDN had very large amplitudes, and it is possible that one or both of these strokes initiated one or more upward discharges from tall, nearby structures.

Photo 2. Upward discharges to a power line in Japan (courtesy of N. Honma)

5.5-3c Coupling of electromagnetic energy into the Sago mine

In **Section 5.5-2** we have seen that there were two, very large, positive cloud-to-ground strokes in the vicinity of the Sago mine at about the time of the explosion, and that there may have been one or more undetected upward lightning discharges that were not detected by the NLDN. Professor Thomas Novak and co-workers have recently discussed the possibility that lightning can cause methane explosions in underground mines during thunderstorms, and they have shown that low-level, corona discharges are one possible cause of ignition[6, 7]. The peak impulse power in a typical

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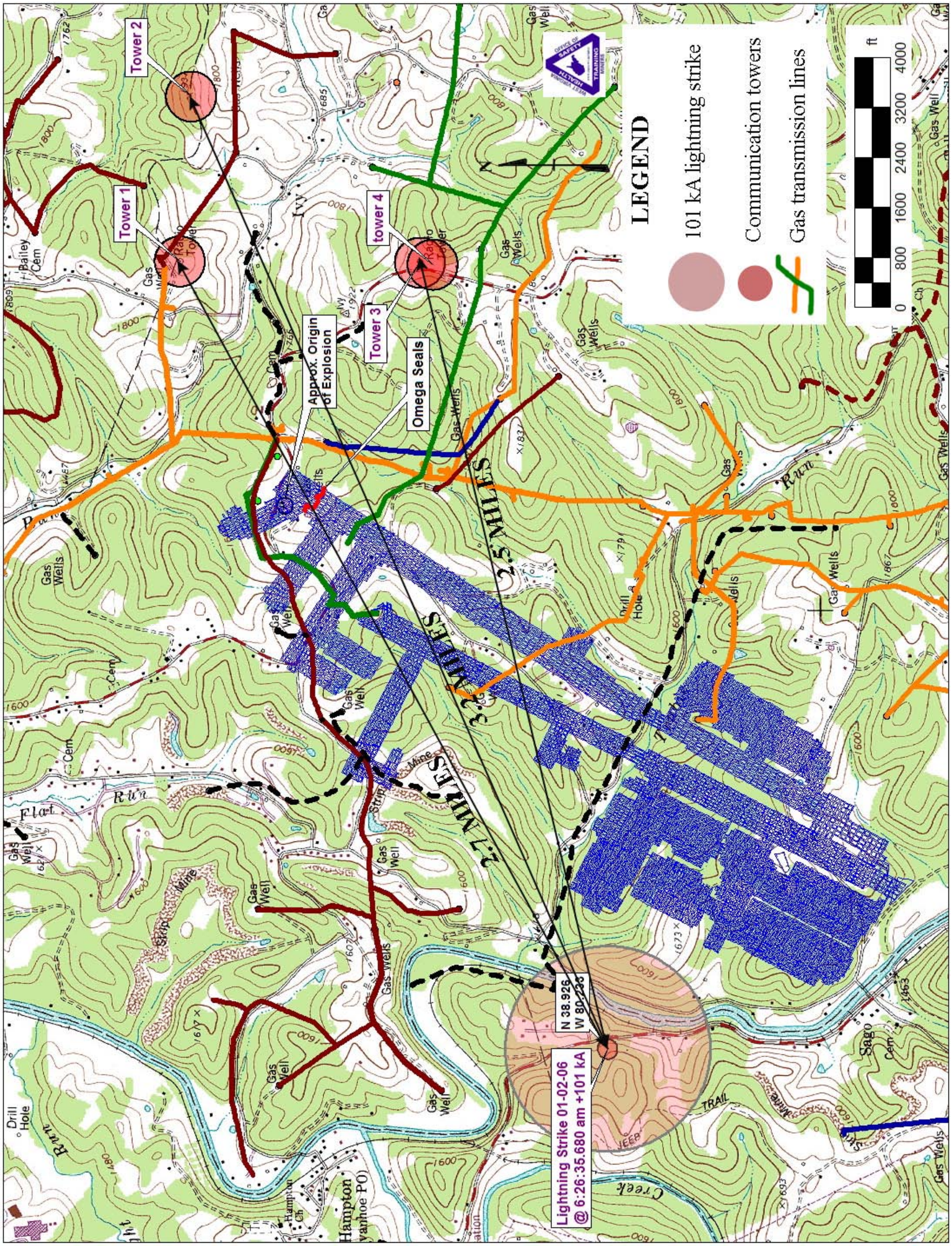
[6] Novak, T. and T. J. Fisher, Lightning Propagation Through the Earth and Its Potential for Methane Ignitions in Abandoned Areas of Underground Coal Mines, *IEEE Trans. on Industry Applications, 37* (6), 1555-1562, 2001.

[7] Sachs, H. K. and T. Novak, Corona-Discharge-Initiated Mine Explosions, *IEEE Trans. on Industry Applications, 41* (5), 1316-1322, 2005.



Map 1. Location of high antennas east of Sago Mine. Upward lighting from such structures can be initiated from cloud-to-ground strikes that occur several miles away.

lightning stroke is of the order of 10,000 megawatts[8], and the impulse current is about a billion times larger than the current in typical corona. A key question in this investigation is "How did the electromagnetic energy from lightning couple into the Sago mine?" We do not have a definitive answer yet, but there are many possibilities. Lightning current could have been conducted directly into the mine on the electric power or other wiring at the mine entrance. A dispatcher at the time of the incident received a painful crackling from the telephone[9], and this in turn is evidence that a high voltage transient was present on the communications wires. The large lightning currents could also have caused transient voltages to appear on the extensive network of gas pipelines and wells near the Sago mine, and a portion of that current could have been conducted into the region of the explosion. Any large loops in metallic conductors, either inside or outside the mine, could have acted as magnetic antennas and created large potential differences (voltages) across any gaps in those loops in response to the time-varying lightning magnetic field. The metallic roof mesh, or any other large masses of metal (like vertical well casings), could also have acted as electric field antennas and caused large voltages to appear on the extremities of those antennas in response to the low frequency electric field in the ground.

There are reports by residents who live on the ridge between the +101 kA stroke location just west of the Sago mine and the towers shown in **Map 1** who describe phenomena associated with an unusually large flash sometime after 6:00 AM. These accounts could be due to an upward or triggered lightning discharge that was initiated by a nearby tower.

The degree to which external electromagnetic fields can propagate into the earth and couple onto structures depends on the thickness of the overlayer, its resistivity, and the frequency of the source. **Figure 1** shows the "skin depth" of a homogeneous material as a function of its resistivity and frequency.

Lightning strokes are a broadband source of electromagnetic energy, and the peak in the power spectrum is typically in the range of a few to a few tens of kilohertz. Positive cloud-to-ground strokes usually contain long, continuing currents and the spectrum of those strokes extends down to

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8 Krider, E. P., On the electromagnetic fields, Poynting vector, and peak power radiated by lightning return strokes, *J. Geophys. Res.*, *97* (D14), 15,913–15,917, 1992.

9 Page 33, starting on line 11 of Statement by William (Bill) Chisolm, February 15, 2006.

frequencies of the order of one kilohertz or less. It should be noted in **Figure 1** that a material with an average resistivity of 100 ohm-meters has a skin depth of 100 meters at frequencies of 3 kilohertz or less.

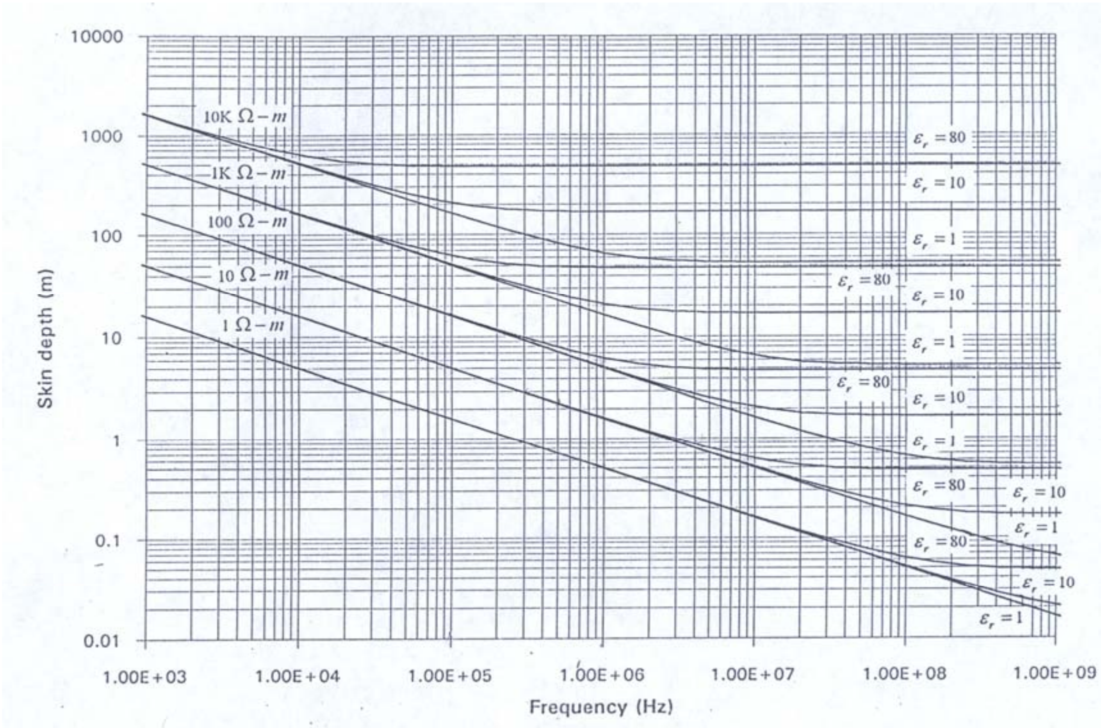


Figure 1. Skin depth as a function of soil resistivity and frequency.

More work is planned on the question of how lightning energy coupled into the Sago mine. In order to clarify which of the many possible mechanisms dominates the coupling, it would be good to measure the voltage transients that appear on various conductors inside the mine when there is natural lightning in the region.

5.5-3d Examination of the surface electrical systems

The poplar tree that was struck by lightning (see **Section 5.5-2**) is approximately three-hundred thirty (330) feet away from the private power distribution line that services the Sago Mine. At the time of the explosion this line serviced only the Sago Mine and the facilities at the Sawmill Run Prep Plant. Because it was in close proximity to such a powerful lightning strike (+101 kA) the line seemed a prime candidate as the path by which lightning could have entered the Sago Mine. (See **Map 2**)

Surface electrical systems were examined by coordinated efforts of MSHA, OMHS&T and representatives of ICG [10] This included an examination of the following:

1) the 12kV power distribution line extends from the Allegheny Power substation on French Creek, southwesterly approximately 2.6 miles to the Sawmill Run Sub-station (**see Map 2**).

2) a 12kV branch line to the Sago Mine that begins just south of the community of Sago and crosses the Buckhannon River north to the Sago Mine

3) a split at the Sago mine where power passes to a separate transformer that powers the stacker belt, mine offices, and pit sump pump, and another split that runs to the Sago Mine substation which steps down the power from 12470 volts to 7200 volts..

4) electric highline feed from the Sago Mine Sub-station underground into Sago mine

French Creek Sub-station

The French Creek sub-station (**see Photo 3**) receives 138,000 volts 3 phase AC from Allegheny Power Company[11] and steps down to 12,470 volts 3 phase AC thru a Delta-Wye Transformer. This power then feeds a substation located behind the Sawmill Run Preparation Plant, (**Photo 4**) on approximately 2.6 miles of privately-owned and maintained power lines (**Photo 5**). It is located near the community of Hampton, West Virginia, where French Creek empties into the Buckhannon River.

Photo 3. French Creek Substation

The 12kV line branches off of this line (**Photo 6**) and feeds the sub-station located at the Sago Mine. (**Photo 7**)

All three sub-stations were checked for possible lightning damage or equipment malfunction. No apparent damage or malfunction was found. Two areas, one on the main line (**Photo 8**)

[10] ICG provided transportation to structures and historical background on the 12kV system

and the other on the branch line (feeding Sago) (**Photo 9**) had possible lightning damage. The location of this damage on the powerline system is shown on **Map 2**. Because no power outages were reported at either the Sago mine or the Sawmill Run Preparation Plant on the morning of January 2, 2006, it could not be determined when this damage occurred. Only eight (8) of the mainline pole structures were not butt-grounded (see **Photo 10**). However three (3) of the eight (8) pole structures that were located closest to the poplar tree that was struck by lightning were not butt-grounded.

The butt-grounds are tied to the overhead ground wire. None of the guy wires were grounded or insulated at the time of the explosion. This was not a requirement when the pole structures were installed, however guy wires located above phase conductors and have a potential of becoming energized are now required to be grounded or insulated. All of the affected guy wires are now either grounded to the system ground or insulated. There are at least two more sets of lightning arrestors between this area and where the high voltage cable enters underground so required lightning protection was being provided. The lightning arrestors are rated at a phase-to-ground voltage (10kV). The damaged center phase insulators (**Photo 8**) have two (2) prominent chips in the lower two bells and this damage could have been caused by lightning. It is unknown when this damage occurred but the insulators are used for insulation purposes—not lightning protection. The displaced earth at the base of the pole and the discolored ground wire could be indications of lightning (**Photo 11**).

Photo 4. Sawmill Run Preparation Plant Sub-station

Photo 5. Section of 2.6 mile 12KV power line

[11] Allegheny Power owns, operates, and maintains this substation.

Photo 6. The 12KV branch line is approximately 1 mile in length line feeding the Sago Sub-station.

Photo 7. Sago Sub-station

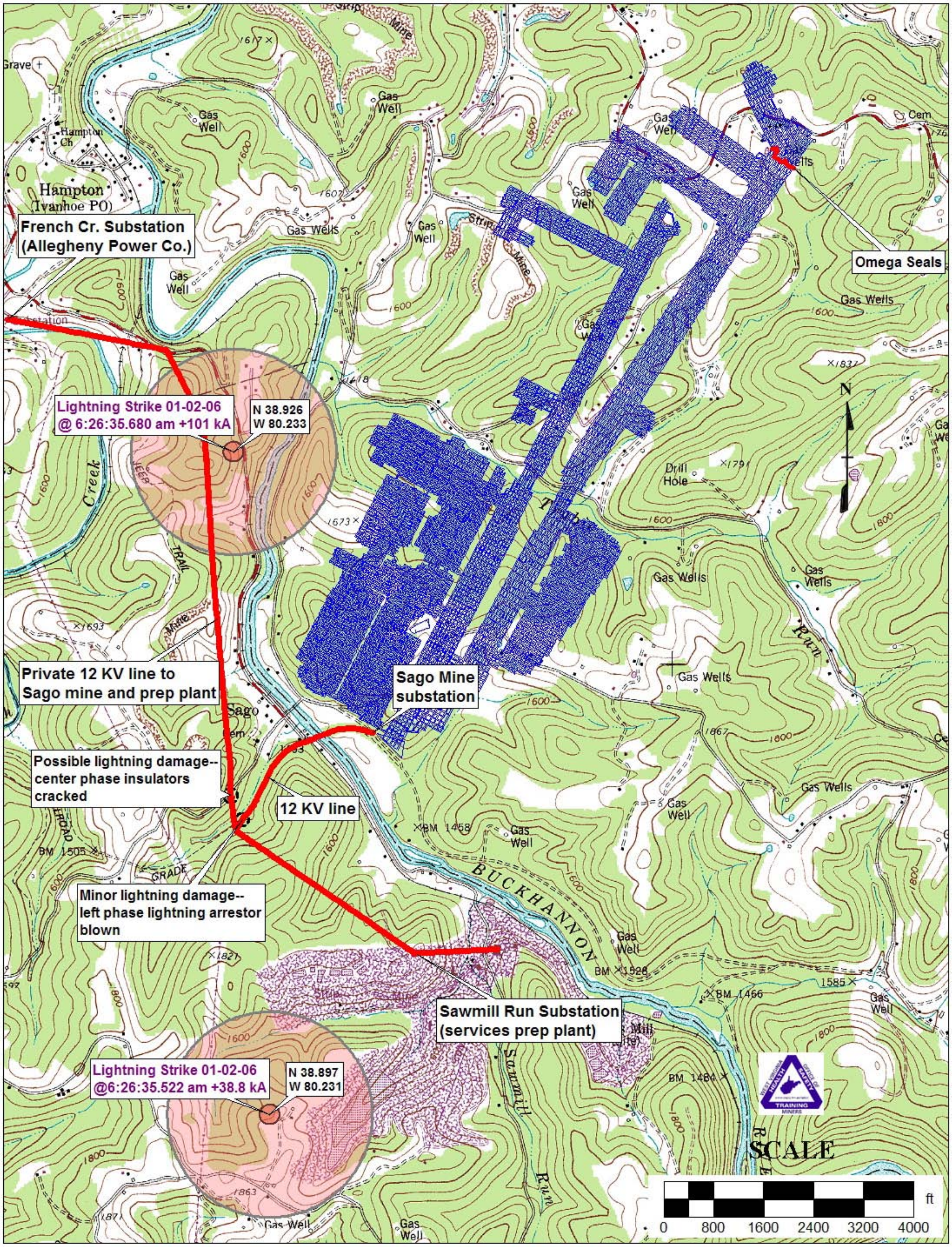
Photo 8. Damaged insulators on the middle phase wire on the main 12KV line

Photo 9. Damaged lightning arrestor on the outside phase of the branch line feeding the Sago sub-station

Photo 10. This two pole structure is butt-grounded at each pole. Note "antenna" atop each pole.

Photo 11. Disturbance at base of pole with the damaged insulators

The main 12kV line has 795mcm ACSR phase conductors and two 336mcm ACSR neutral/ ground conductors located above the phase conductors. The main 12kV line was installed sometime in the mid 1970's. The branch line was installed in 1999. The phase conductors of the branch line are 336 mcm ACSR.



Map 2. Location map showing Sago Mine No. 1, the Sawmill Run and Sago substations, the 12 kV power distribution line, minor damage found on those lines, and the lightning strikes recorded at 6:26:35 AM EST.

5.5-3e Examination of the underground electrical systems

Two electrical investigation teams, each consisting of OMHS&T, MSHA, ICG, and UMWA personnel inspected and/or tested the electrical equipment and electrical installations for possible lightning damage or malfunction.

The two investigation teams split up and worked in different areas of the mine. Two sections of high voltage cable were physically damaged during the explosion, one inby the one-left switch and another section inby the two-left switch. This condition tripped a high voltage circuit breaker at a splitter box located near the # 2 Belt Drive. There was no interruption of power on the surface. No evidence was found of any electrical equipment malfunction or failure of electrical circuits that may have triggered the methane explosion behind the seals. No apparent lightning damage was found on any of the mine-site equipment or electrical installations on the surface or underground, although some damage to the 12kV distribution line leading to the mine was found, as previously noted. Thirty-three (33) non-contributing violations were issued by OMHS&T (see **Appendix 5.1:** *Statistics and Fact-finding).*

Conductivity testing

Because no continuous metallic conductors were found across the seals that could have provided an electrical path from one side of the seals to the other, and because several significant gaps exist in the wire roof mesh leading back to the approximate origin of the explosion, a series of resistivity tests were performed to determine if electricity could have found a path of low resistance directly through roof rock strata and/or floor strata. Four tests were performed in this regard along various locations between the tailpiece of #4 Belt and up to the approximate origin of the explosion.

Test 1

Resistivity testing of the roof bolts, wire mesh screen, and mine floor was conducted on February 14, 2006; (**Figure 3)** to determine if a low-resistance electrical path exists from outside the sealed area to an area behind the seals where the explosion is believed to have originated. Testing was first conducted from the end of the track and continued back to this area.

Four pole resistivity tests (**Figure 2**) were conducted using a NGI Unilap GEO x resistance tester. Four metal rods were driven in the mine floor at 20 foot intervals, starting at the end of the track and continuing up into the region where the explosion is believed to have originated. Measurements were taken every 60 feet for a total distance of approximately 1250 feet. Readings were also taken between roof bolts and/or wire mesh screen in the same areas.

Resistance measurements between roof bolts and/or wire mesh screen for the first 1130 feet averaged 3 ohms. Resistance measurements between the rods in the mine floor averaged 7.5 ohms. Resistance measurements across the next 120 feet ranged from 3000 ohms to infinity.

These resistance measurements were suspect due to roof with possible carbon traces on the roof bolt plates and/or wire mesh screen. For this reason additional tests were conducted on April 3 and 4, 2006, where 5/8 diameter holes were drilled into the mine roof and steel nails were installed with a Hilti nail gun. This was done to isolate the nails from the carbon on the roof surface.

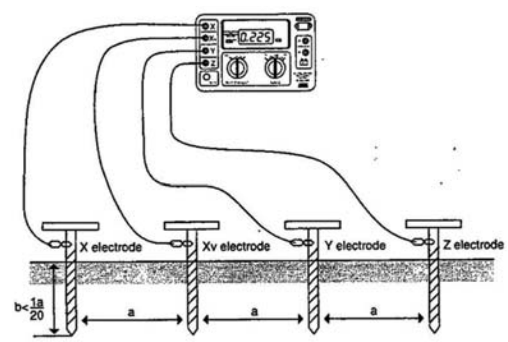


Figure 2 Four Pole Resistivity Test

<u>Test 2</u>

A four pole resistivity test was conducted on April 3, 2006, (**Figure 4**) across the area where the seals had been installed prior to January 2, 2006.

- The resistance between the installed **roof nails** ranged from 2.3 ohms to 17000 ohms.
- The resistance between the installed **floor nails** ranged from 7 ohms to 12.8 ohms.
- The resistance between the **roof bolts** ranged from 0 ohms to 3.5 ohms.

The same four pole resistivity tests were conducted from the number 4 belt conveyor tailpiece structure up to the area of the blown out seal in the number 5 entry.

- The resistance between the installed **roof nails** ranged from 3,300 ohms to 61,000 ohms.
- The resistance between the installed **floor nails** ranged from 5.4 ohms to 14.9 ohms.
- The resistance between the **roof bolts** ranged from 0 ohms to .004 ohms.

The same four pole resistivity tests were conducted in the number 6 track entry.

- The resistivity between the installed **roof nails** ranged from 3.9 ohms to 6,200 ohms.
- The resistance between the **floor nails** ranged from 11.7 ohms to 12.7 ohms.
- The resistance between the **roof bolts** ranged from .003 ohms to 8.3 ohms.

Test 3

Four pole resistivity tests were conducted on April 4, 2006, (**Figure 5**) across the gaps in the wire mesh roof screen in several locations in the formerly sealed area. 5/8 diameter holes were drilled into the mine roof and steel nails were installed with a Hilti nail gun. The nails were installed at different intervals (depending on the length of the gap in the roof screen) and measurements were taken with a NGI Unilap GEO x resistance tester in locations # 1 thru 4. Measurements at location #5 were taken with a Fluke Model # 27 Volt-Ohm meter.

- In location #1 the roof nails were installed on 12 foot centers and the measured resistance ranged from 0.02 ohms to 3 ohms.
- Location #2 (3 foot centers) measurements ranged from 1 to 4.7 ohms of resistance.
- Location #3 (4 foot centers) measurements ranged from 1 to 51 ohms of resistance.
- Location #4 (10 foot centers) measurements ranged from 0.004 ohms to 2.1 ohms of resistance.
- Location #5 measurements were taken with a Volt-Ohm meter and were 4 ohms between roof bolts and 4 ohms between wire mesh screen.

Test 4

Tests were conducted using a megger and a Volt-Ohm meter at several locations including using approximately 1200 feet of 12/2 AWG solid copper wire to measure the resistance between the number 4 Belt conveyor tailpiece and roof bolts and/or wire mesh screen located in the approximate origin of the explosion. (see **Figure 6**). Resistance measurements were also taken between the track and wire mesh screen (Location #1) 2 ohms, between the track and the number 4 Belt tailpiece (Location #2) 100 ohms. Also at Location #2 the measured resistance between the #4 Belt tailpiece and the wire mesh screen was 0.439 ohms. A Volt-Ohm meter was used for the resistance measurements between the #6 Belt Power Center and the track (Location #3) and showed 1.2 ohms and between the Power Center and a roof bolt (Location #3) it showed 600 Ohms. Testing at Location #4 utilized the 1200 feet of solid copper wire stretched from the #4 Belt tailpiece to the approximate area of the explosion. Measured resistance between the #4 Belt tailpiece and roof bolts in this area ranged from 100 to 175 ohms when using a megger and 40 ohms when using Volt-Ohm meter. Measured resistance between the tailpiece and wire mesh screen in this area was 100 ohm when using a megger and from 50-52 ohms when using a Volt-ohm meter. The resistance of the 12/2 solid copper wire is 1.6 ohms of resistance per 1000 foot.

In addition to these tests a geophysical log for corehole SF 52-06 shows that the upper ½ of the interval between a rider[12] seam that is present approximately 60 feet above the coal seam had the lowest average resistivity in the overburden column; averaging around 100 ohms. The bottom ½ of the interval was not logged.

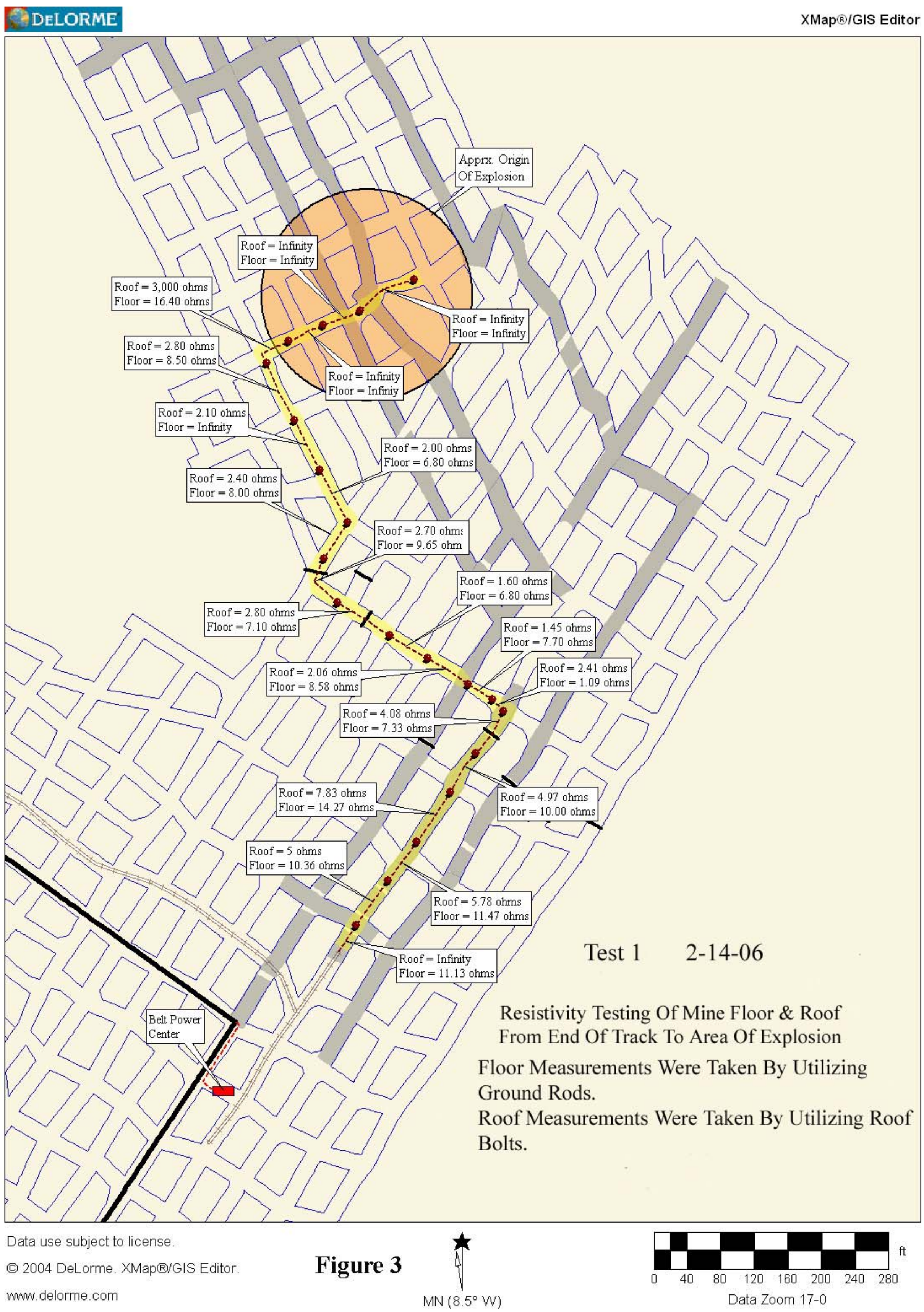
Summary of findings

No evidence has been found of damage to the 12 kV power distribution system, to the substations, surface power systems, or underground power systems that can be attributed to the lightning strike at 6:26:35 AM on January 2, 2006.[13] If stray current or induced currents made their way through these systems, it would not have found an uninterrupted connection over metallic conductors the entire way to the region of the explosion origin. The only metallic conductors extending past the mainline track and belt are the mats of wire roof mesh installed in the track entry, belt entry, and primary escapeway. There are numerous gaps in the wire roof mesh.

The shale roof in the mine is high in clay content, and from the results of the electrical tests conducted in the roof it appears to have low resistivity. This by itself is not necessarily evidence this was the path the electricity from lightning traveled. Testing of the ability of mine infrastructure to deliver a sufficient amount of current that deep into the mine has been recently performed by Sandia National Laboratories for MSHA. At the time of this writing the data are preliminary and has not been made available to OMHS&T.

[12] Also called the Upper Kittanning seam.

[13] The damaged lightning arrestor on the branch line to Sago Mine was likely caused by lightning and could have occurred that day. The cracked insulator and ground disturbance shown in Photos 8 and 11 may or may not be lightning-related.


DELORME
XMap®/GIS Editor
Apprx. Origin Of Explosion
Roof = Infinity Floor = Infinity
Roof = 3,000 ohms Floor = 16.40 ohms
Roof = Infinity Floor = Infinity
Roof = 2.80 ohms Floor = 8.50 ohms
Roof = Infinity Floor = Infiniy
Roof = 2.10 ohms Floor = Infinity
Roof = 2.00 ohms Floor = 6.80 ohms
Roof = 2.40 ohms Floor = 8.00 ohms
Roof = 2.70 ohms Floor = 9.65 ohm
Roof = 1.60 ohms Floor = 6.80 ohms
Roof = 2.80 ohms Floor = 7.10 ohms
Roof = 1.45 ohms Floor = 7.70 ohms
Roof = 2.06 ohms Floor = 8.58 ohms
Roof = 2.41 ohms Floor = 1.09 ohms
Roof = 4.08 ohms Floor = 7.33 ohms
Roof = 7.83 ohms Floor = 14.27 ohms
Roof = 4.97 ohms Floor = 10.00 ohms
Roof = 5 ohms Floor = 10.36 ohms
Roof = 5.78 ohms Floor = 11.47 ohms
Roof = Infinity Floor = 11.13 ohms
Test 1 2-14-06
Resistivity Testing Of Mine Floor & Roof From End Of Track To Area Of Explosion
Floor Measurements Were Taken By Utilizing Ground Rods.
Roof Measurements Were Taken By Utilizing Roof Bolts.
Belt Power Center
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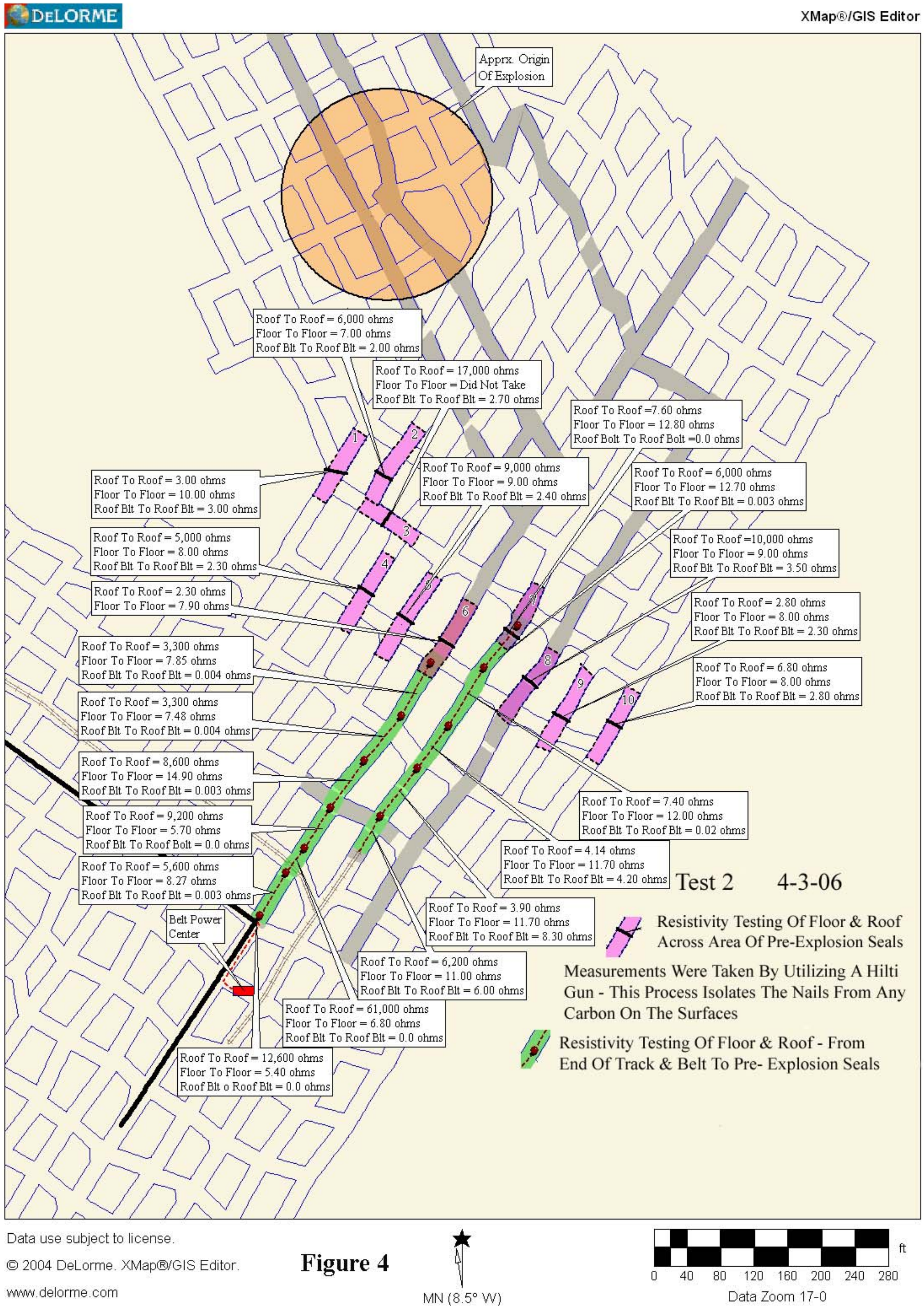
MN (8.5° W)
ft
0 40 80 120 160 200 240 280
Data Zoom 17-0

Figure 3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XMap®/GIS Editor
Apprx. Origin
Of Explosion
Roof To Roof = 6,000 ohms
Floor To Floor = 7.00 ohms
Roof Blt To Roof Blt = 2.00 ohms
Roof To Roof = 17,000 ohms
Floor To Floor = Did Not Take
Roof Blt To Roof Blt = 2.70 ohms
Roof To Roof =7.60 ohms
Floor To Floor = 12.80 ohms
Roof Bolt To Roof Bolt =0.0 ohms
Roof To Roof = 3.00 ohms
Floor To Floor = 10.00 ohms
Roof Blt To Roof Blt = 3.00 ohms
Roof To Roof = 9,000 ohms
Floor To Floor = 9.00 ohms
Roof Blt To Roof Blt = 2.40 ohms
Roof To Roof = 6,000 ohms
Floor To Floor = 12.70 ohms
Roof Blt To Roof Blt = 0.003 ohms
Roof To Roof = 5,000 ohms
Floor To Floor = 8.00 ohms
Roof Blt To Roof Blt = 2.30 ohms
Roof To Roof =10,000 ohms
Floor To Floor = 9.00 ohms
Roof Blt To Roof Blt = 3.50 ohms
Roof To Roof = 2.30 ohms
Floor To Floor = 7.90 ohms
Roof To Roof = 2.80 ohms
Floor To Floor = 8.00 ohms
Roof Blt To Roof Blt = 2.30 ohms
Roof To Roof = 3,300 ohms
Floor To Floor = 7.85 ohms
Roof Blt To Roof Blt = 0.004 ohms
Roof To Roof = 6.80 ohms
Floor To Floor = 8.00 ohms
Roof Blt To Roof Blt = 2.80 ohms
Roof To Roof = 3,300 ohms
Floor To Floor = 7.48 ohms
Roof Blt To Roof Blt = 0.004 ohms
Roof To Roof = 8,600 ohms
Floor To Floor = 14.90 ohms
Roof Blt To Roof Blt = 0.003 ohms
Roof To Roof = 7.40 ohms
Floor To Floor = 12.00 ohms
Roof Blt To Roof Blt = 0.02 ohms
Roof To Roof = 9,200 ohms
Floor To Floor = 5.70 ohms
Roof Blt To Roof Bolt = 0.0 ohms
Roof To Roof = 4.14 ohms
Floor To Floor = 11.70 ohms
Roof Blt To Roof Blt = 4.20 ohms
Roof To Roof = 5,600 ohms
Floor To Floor = 8.27 ohms
Roof Blt To Roof Blt = 0.003 ohms
Test 2 4-3-06
Roof To Roof = 3.90 ohms
Floor To Floor = 11.70 ohms
Roof Blt To Roof Blt = 8.30 ohms
Belt Power
Center
Resistivity Testing Of Floor & Roof
Across Area Of Pre-Explosion Seals
Roof To Roof = 6,200 ohms
Floor To Floor = 11.00 ohms
Roof Blt To Roof Blt = 6.00 ohms
Measurements Were Taken By Utilizing A Hilti
Gun - This Process Isolates The Nails From Any
Carbon On The Surfaces
Roof To Roof = 61,000 ohms
Floor To Floor = 6.80 ohms
Roof Blt To Roof Blt = 0.0 ohms
Resistivity Testing Of Floor & Roof - From
End Of Track & Belt To Pre- Explosion Seals
Roof To Roof = 12,600 ohms
Floor To Floor = 5.40 ohms
Roof Blt o Roof Blt = 0.0 ohms
1
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MN (8.5° W)
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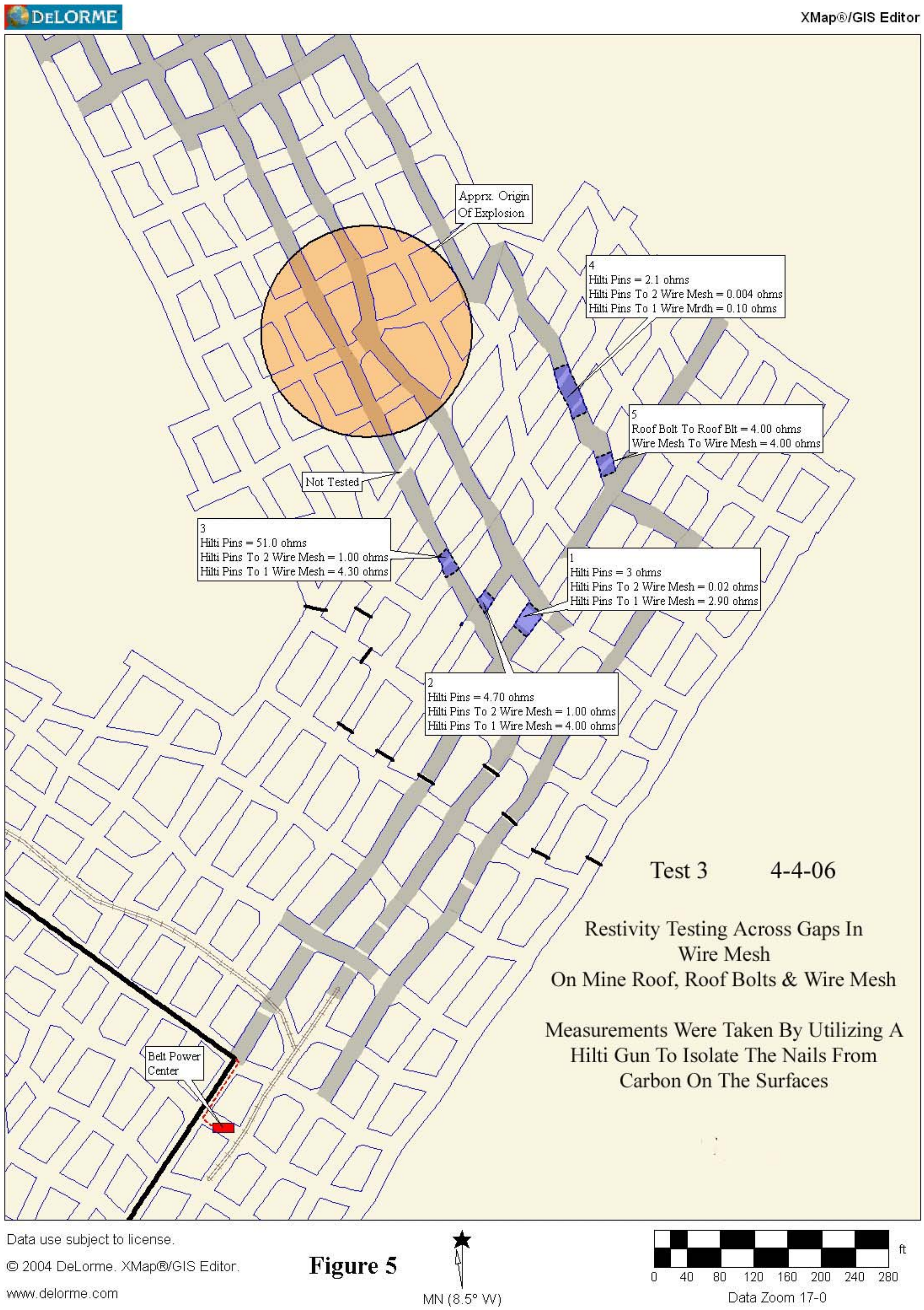
Data Zoom 17-0

Figure 4


DeLorme
XMap®/GIS Editor
Apprx. Origin
Of Explosion
4
Hilti Pins = 2.1 ohms
Hilti Pins To 2 Wire Mesh = 0.004 ohms
Hilti Pins To 1 Wire Mrdh = 0.10 ohms
5
Roof Bolt To Roof Blt = 4.00 ohms
Wire Mesh To Wire Mesh = 4.00 ohms
Not Tested
3
Hilti Pins = 51.0 ohms
Hilti Pins To 2 Wire Mesh = 1.00 ohms
Hilti Pins To 1 Wire Mesh = 4.30 ohms
1
Hilti Pins = 3 ohms
Hilti Pins To 2 Wire Mesh = 0.02 ohms
Hilti Pins To 1 Wire Mesh = 2.90 ohms
2
Hilti Pins = 4.70 ohms
Hilti Pins To 2 Wire Mesh = 1.00 ohms
Hilti Pins To 1 Wire Mesh = 4.00 ohms
Test 3 4-4-06
Restivity Testing Across Gaps In
Wire Mesh
On Mine Roof, Roof Bolts & Wire Mesh
Measurements Were Taken By Utilizing A
Hilti Gun To Isolate The Nails From
Carbon On The Surfaces
Belt Power
Center
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MN (8.5° W)
0 40 80 120 160 200 240 280
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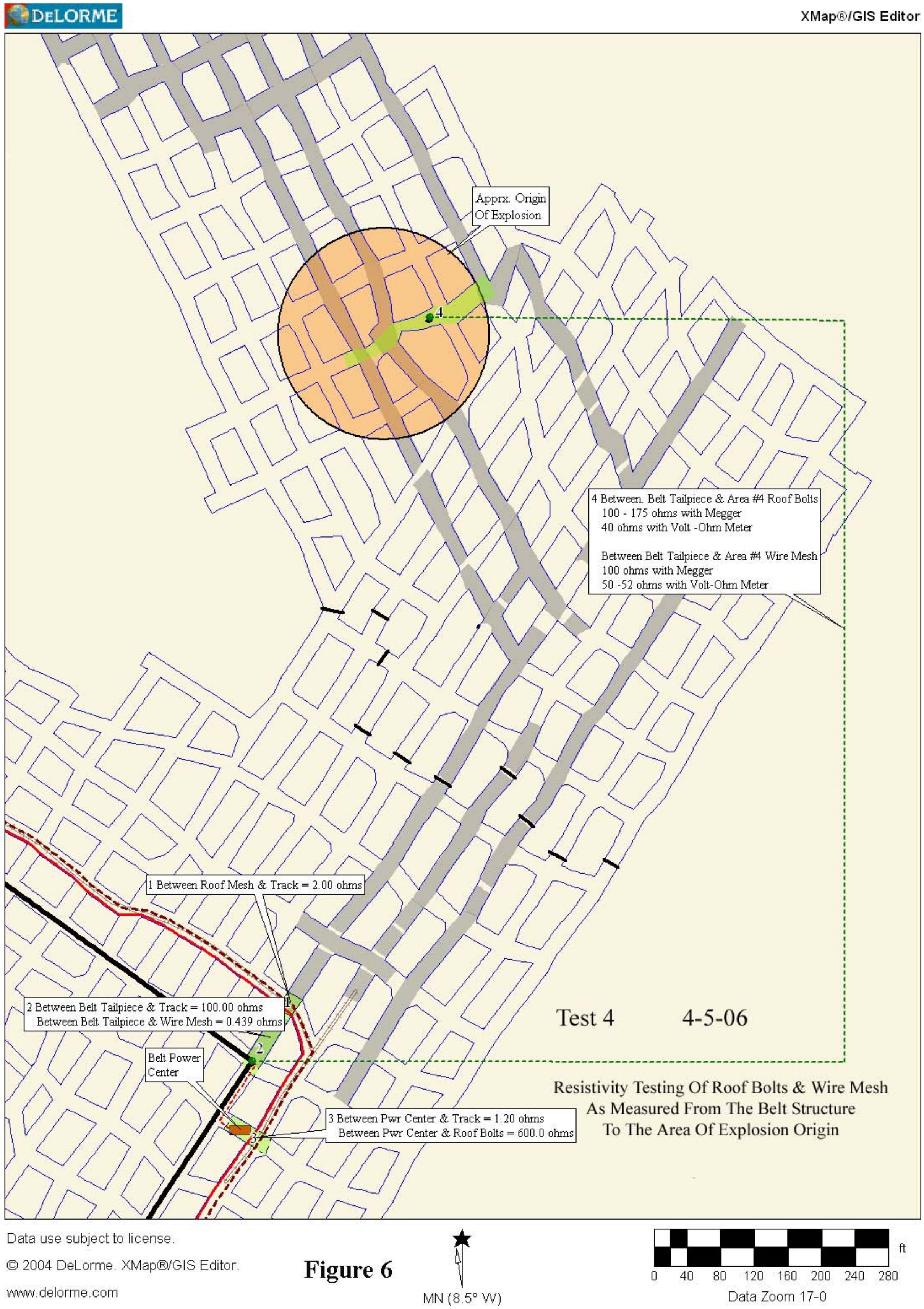
Data Zoom 17-0

Figure 5


DELORME
XMap®/GIS Editor
Apprx. Origin Of Explosion
4
4 Between. Belt Tailpiece & Area #4 Roof Bolts
100 - 175 ohms with Megger
40 ohms with Volt -Ohm Meter
Between Belt Tailpiece & Area #4 Wire Mesh
100 ohms with Megger
50 -52 ohms with Volt-Ohm Meter
1 Between Roof Mesh & Track = 2.00 ohms
2 Between Belt Tailpiece & Track = 100.00 ohms
Between Belt Tailpiece & Wire Mesh = 0.439 ohms
Belt Power Center
3 Between Pwr Center & Track = 1.20 ohms
Between Pwr Center & Roof Bolts = 600.0 ohms
Test 4
4-5-06
Resistivity Testing Of Roof Bolts & Wire Mesh
As Measured From The Belt Structure
To The Area Of Explosion Origin
Data use subject to license.
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www.delorme.com
MN (8.5° W)
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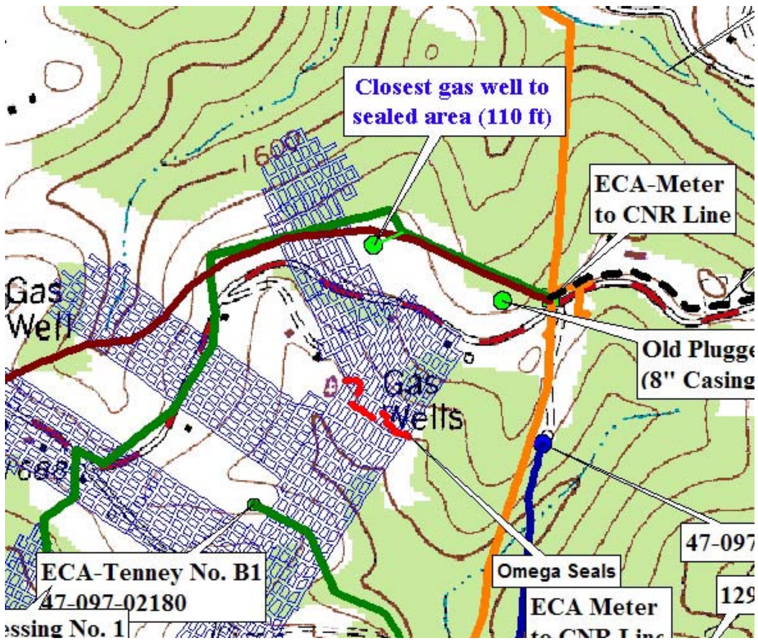
0 40 80 120 160 200 240 280
Data Zoom 17-0

Figure 6

5.5-3f Gas lines and wells

An extensive network of gas lines connects conventional gas wells on the surface over the Sago Mine and surrounding areas. Two lines are known to cross the surface over the Old 2nd Left sealed section. One well is located approximately one-hundred ten (110) feet from the sealed area mine works (see **Map 3**). A map showing the geometry of these lines within a 1.5 mile radius of Old 2nd Left Section is given in **Map 4.** A larger and more detailed map is included in **Appendix 5.5-3**: *Map of Gas Lines and Wells.*



Map 3. The closest gas well to the sealed area is approximatel 110 ft.

The gas line network contains seven (7) separate owner-operators. The main gas transmission line shown (see **Map 4**) gathers gas from feeder lines that are predominantly steel pipelines of approximately two (2) inch diameters, although occasionally small sections of plastic line are used. Approximately sixty (60) active gas wells and approximately twenty-seven (27) miles of active gas pipelines exist within a 1.5- mile radius over the top of the sealed area at Sago. The average depth of these wells is approximately 3800 feet. With the assistance of representatives of the various operating companies involved in this gas line network, OMHS&T prepared a detailed map showing the location of all known wells and lines within this area for purposes of determining whether they may have been involved in the transmission of lightning current into the sealed area.

Any large loops in electrical conductors, either inside or outside the mine, could have acted as a magnetic antenna and produced a large potential difference (voltage) across any gap in that loop in response to the lightning magnetic field. A metal gas well casing could act as an electric field antenna and cause large voltages to appear at the extremities of the antenna if it is exposed to a high electric field[14].

Lightning-related explosions in longwall gob areas that are near networks of methane degasification wells and pipeline systems have been documented in previous reports[15]. Deep gas wells[16] (like those in the Sago area) on the other hand rarely have steel casings that penetrate from the surface into the region of an active mine because of the recognized dangers of doing so. In the case of Sago Mine, there are several wells near the mine, but none pass through the mine void. The closest active well to the Old Second Left section were the Omega seals were located was approximately 110 feet from the eastern perimeter of the mine works.

Two gas lines run eastward from the general vicinity of the 101+ kA lightning strike. These are referred to for purposes of this illustration as the Trubie Run Gas Line and the Ridgetop Gas Line (see **Map 4**). These both connect to the north-south trending Main Gas Transmission Line. Descriptions of these two lines are contained in **Appendix 5.5-3:** *Description of Gas Lines and Wells.*

Conductivity testing

Soil resistivity testing was conducted at a gas well (**Photo 12**) located on the surface near the underground sealed area on January 18, 2006. A three (3) pole soil resistivity test was preformed using a model DET5/4D Megger (**Figure 7**). The metal well casing was used for one connection and ground rods approximately eight (8) inches in length were driven into the ground at distances of thirty (30) feet and sixty (60) feet from the well. 2.62 ohms of resistance was measured. Measurements were then taken in a radial sweep pattern of

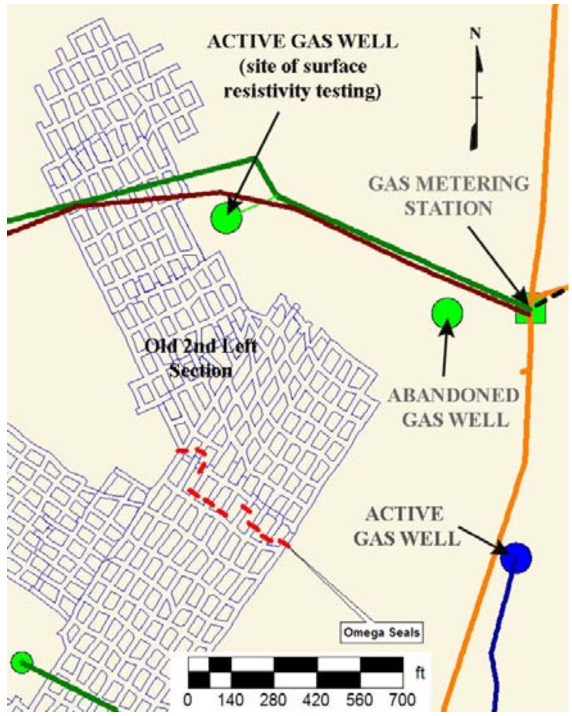
[14] Dr. E.P. Krider, Dept. of Atmospheric Sciences, University of Arizona, November, 2006.

[15] H.K. Sacks, T. Novak; Corona Discharge-Initiated Mine Explosions; IEEE Transactions on Industry Applications, VOL. 41, pp. 1316-1322, 2005.

[16] Deep is defined here as 3500 to 4000 feet and target gas reservoirs that are unrelated to coal degasification wells which are sometimes drilled ahead of mining and in the gob of longwall-mined areas for purposes of recovering liberated methane from coal.

approximately thirty (30) feet each. Only two additional readings were taken and they were 4.83 ohms and 5.6 ohms of resistance.

Photo 12. Nearest known gas well to the Old 2nd Left Section. Soil resistivity tests were conducted here.



Map 3A. Location of the nearest active gas well to Old 2nd Left Section.

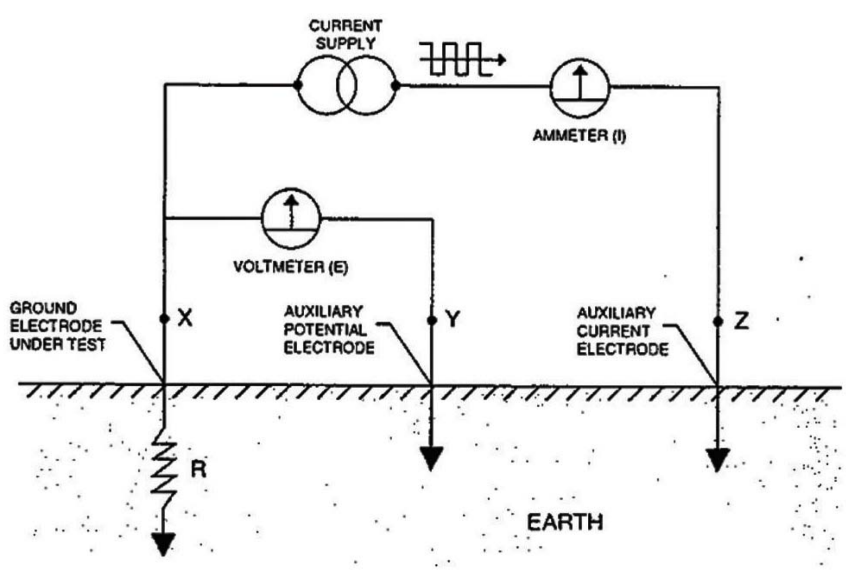
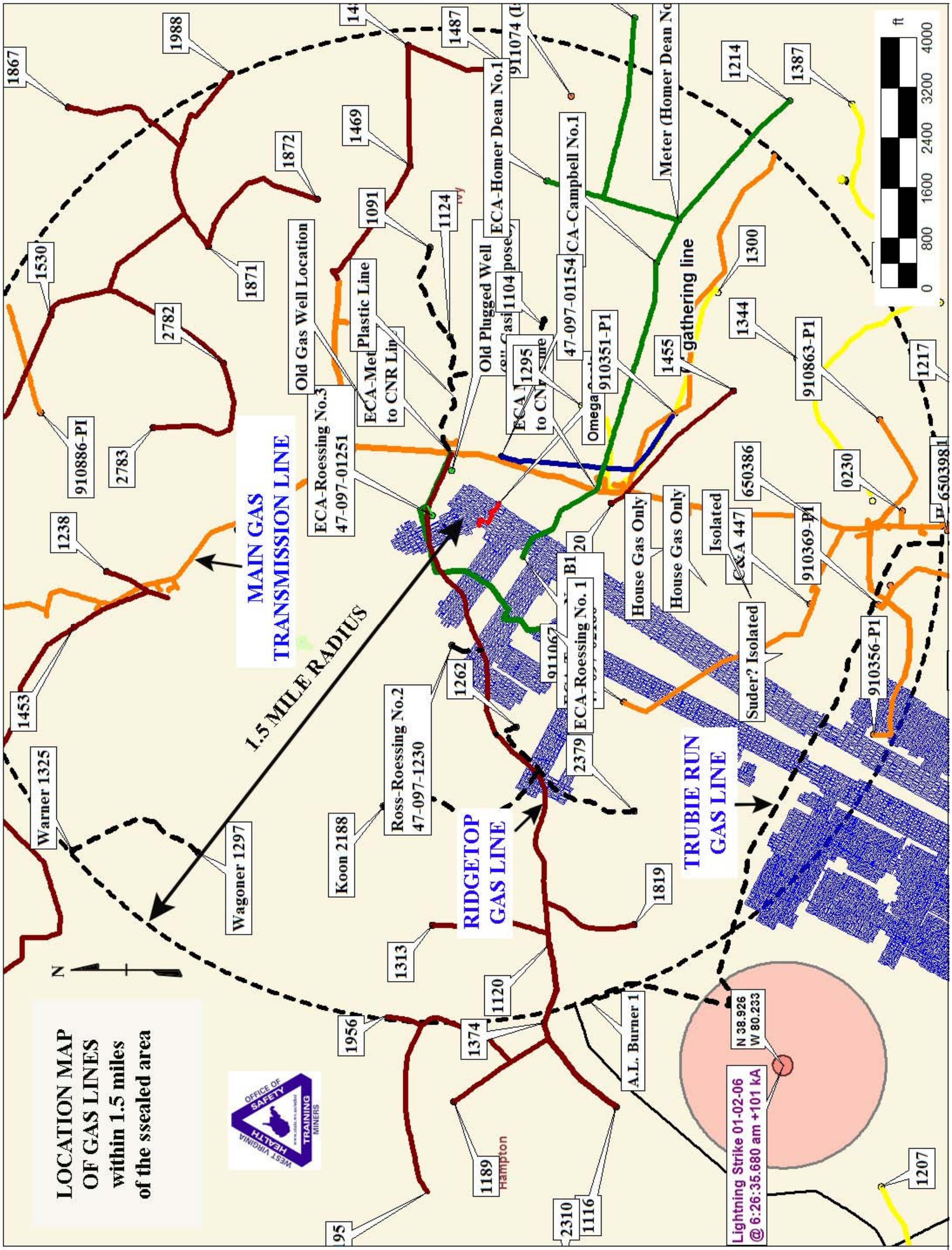


Figure 7. Three pole Resistivity testing



Map 4. Illustration of the location of gas wells and gaslines within a 1.5-mile radius of the Old Second Left Section of Sago Mine.

Summary

All known gas well and gas line owners and operators in the area were contacted to inquire if there was any damage to their equipment or infrastructure from the electrical storms of January 2, 2006. None were reported. Almost all the lines and wells within a 1.5 mile radius around Old 2nd Left Section were traveled and examined at the surface for evidence of damage. No visible damage attributable to lightning was discovered in the course of this work.

Work is still on-going to determine whether the network of gas wells and gaslines may have played a role in coupling high voltages into the sealed area, and particularly with respect to any upward lightning that may have been initiated by tall towers several miles away. A network of vertical gas wells 4000 deep connected to a network of gaslines on the surface could also have acted as a large electric field antenna in the ground at low frequencies.

5.5-3g Earth conduction

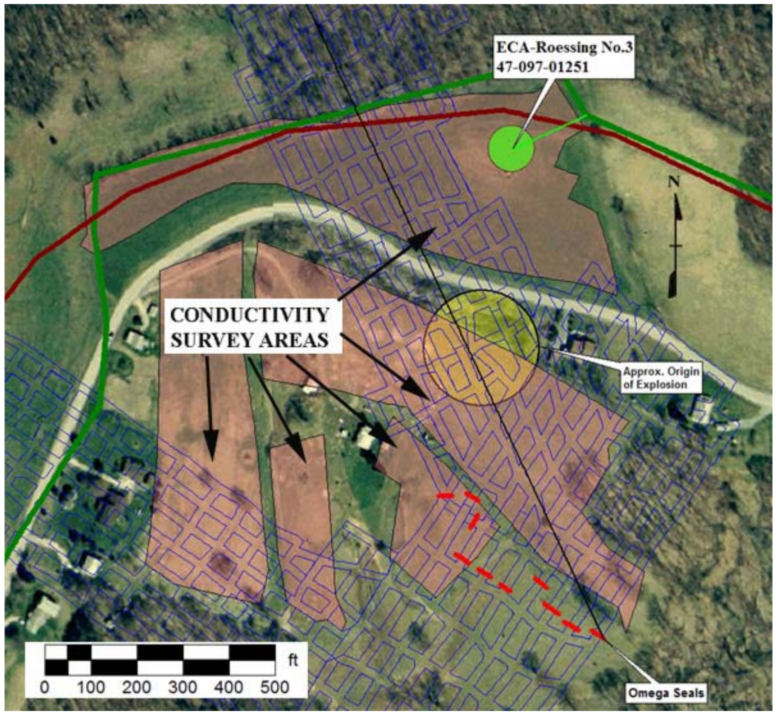
In July 2006, hydroGEOPHYSICS, Inc (HGI) performed a series of geophysical surveys for International Coal Group (ICG), involving the surface and underground areas of the Sago Mine Old 2nd Left section. The objective of this geophysical investigation was to characterize and map subsurface conditions in order to determine if a specific electrical pathway existed. This electrical path could have originated from either anthropogenic[17] features or natural geologic features.

Two different surveys were performed:

1) Electromagnetic Conductivity Survey

This involved searching for metallic infrastructure such as pipelines, wells, powerlines, or other features that could have provided a low resistance path from the surface to the underground mine works. Testing methods involved magnetic gradiometer (MAG survey) and electromagnetic induction (EM survey **Map 5**).

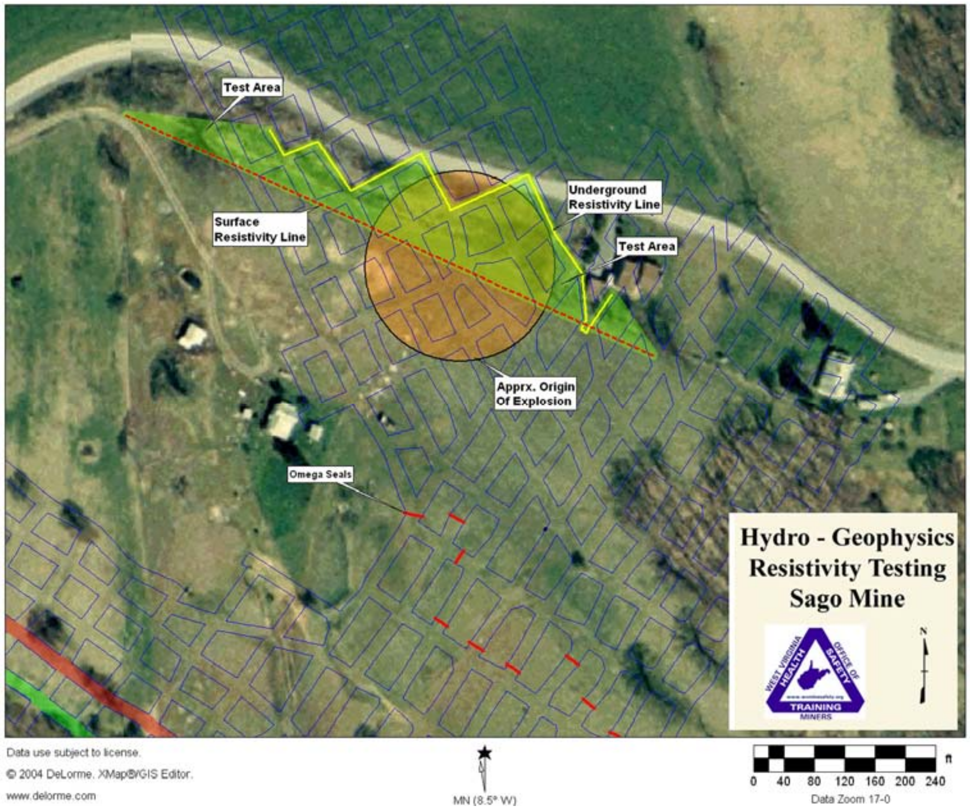
[17] man-made origins



Map 5: Location the areas where the electromagnetic conductivity surveys were performed.

2) High Resolution Resistivity Survey

This involved measuring the electric potential on a series of electrodes while injecting current on a nearby electrode. Testing methods involved High Resolution Resistivity (HRR) survey which utilized a nearby recently-drilled open borehole to drop lines to the mine to measure electric potentials between the surface and underground at various intervals along a baseline (see **Map 6**). The survey was arranged such that a set of electrodes at the surface could be used in combination with electrodes on the mine roof. Testing occurred over the vicinity of the approximated origin of the explosion.



Map 6: Location of area where high-resolution resistivity survey was performed

This survey consisted of individually wiring existing roof bolts (total of 56) in the mine to a communication center and connecting electrodes (total of 56) placed on the surface to the same communication center. An electrical current at varying frequencies (5, 7, 10, 15 and 20 kHz) was injected to an individual surface electrode and resistivity readings were recorded from all the wired roof bolts. This was repeated, injecting current to all 56 electrodes individually. This procedure was then reversed by injecting current to an individual roof bolt and recording resistivity at all the wired surface electrodes. Each roof bolt (total of 56) was injected with electrical current. The data were then processed to determine if any electrically conducting structures existed within the test area.

<u>Results of the testing:</u>

- No vertical well casings were detected within the survey area.
- No compelling vertically oriented conductive zones that could act as an electrical conduit were detected.

5.5-3h Verizon telephone lines

The poplar tree that is believed to have been the strike object of the +101 kA lightning stroke is located about 50ft from a buried telephone utility line that is owned by Verizon. This line was examined for evidence of lightning damage.

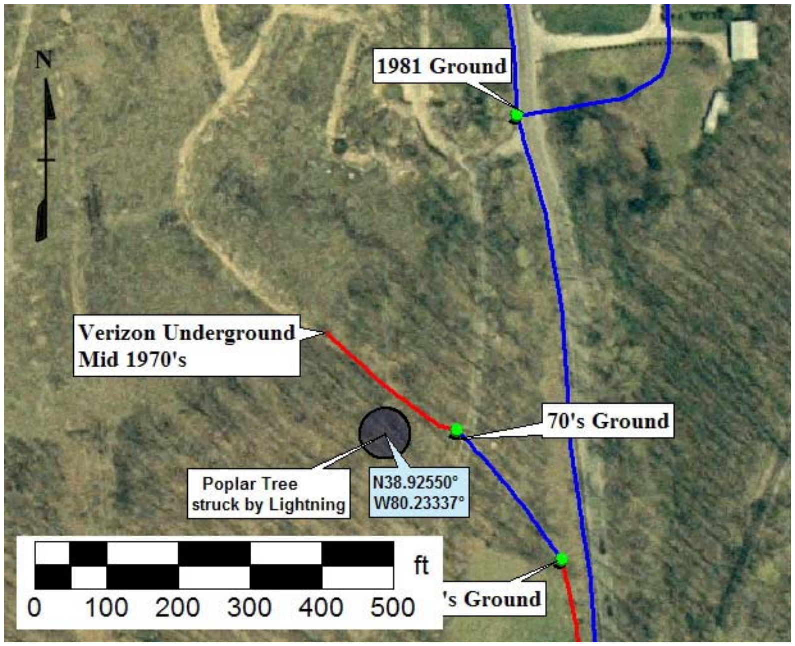


Photo 13. A buried telephone cable lies within approximately 50' of the poplar tree that was struck by lightning,

In mid May 2006 the area engineer for Verizon Telephone Company accompanied OMHS&T personnel on a field inspection of the telephone lines near the ICG – Sago Mine. There are two separate lines that service the Sago area and pass near the poplar tree lightning strike.

The first telephone line was installed in the mid 1970's. This is a buried line that passes closest to the lightning strike and does not service the Sago Mine. It is also the line that spurs off and feeds the nearby residence (the family that lost service immediately after the lightning strike) and is referred to as the 70's line on the attached map. The second line was installed in 1981 (and is referred to as the 1981 Line) and runs parallel to the Sago Road. It is an aerial line that starts at Route 20 to about halfway between the lightning strike area and the Sago Mine. This line then becomes a buried line and parallels the mid 70's line along the Sago Road. The distance between the 1970's buried line and the 1981 buried line is approximately 2 feet horizontally. The 1981 line services the Sago Mine.

Photo 14: Junction box of 1970's line (closest box to lightning-struck poplar tree.

Photo 15: Junction box of 1981 line - where line changes from aerial to buried

The Verizon engineer indicated that when the lines are spliced a junction box is used. At each junction box the line is grounded, and the ground is common with the incoming line and the outgoing line. This is done to insure that no interference will cause poor line service to the customers. The location of the junction box is site-specific and is referred to as: 70's Ground for the 1970's Line and 1981 Ground for the 1981 Line, on the attached map. These two lines are grounded separately.

The nearest line that the lightning could have contacted and used as a conductor of electricity is the 70's buried line. The closest junction box (70's Ground 1) to the poplar tree is approximately one hundred (100) feet. At this time the line temporarily becomes aerial for a road crossing and then is buried again at junction box (70's Ground 2). This is where the Verizon engineer indicated repair service for the nearby resident was done. OMHS&T staff had found wire at the previous junction box (70's Ground 1) and assumed that the repairs were there.

Photo 16: Junction boxes of the 1970's buried line and the 1981 buried line.

Photo 17: Typical grounding of buried cable at junction box

The Verizon engineer indicated that that box is safely off the road and the service/repair men often use it to trouble shoot. They can narrow down any problem by checking for faults and determine if the problem is inby or outby that box. When the "70's Ground 1" Junction Box was opened it was found that rodents were living in the junction box, and several wires had places where they had eaten the insulation from them (see **Photo 18**). The wire insulation was tarnished from animal waste. The nest was rather large; the occupants had been there for quite some time. Connections are coated with a gel to prevent moisture intrusion at the splices. The individual insulated lead wires in the telephone line are roughly 19 gauge wires (visually the diameter of "0.5 mm pencil lead"). The Verizon engineer stated that the 70's line and 1981 line are 70 to 80 pair lines (140 to 160 leads).

Photo 18: Mouse nest in 1970's junction box closest to lightning strike**.**

In order for electricity from the lightning strike at the poplar tree to have traveled to the Sago Mine via the telephone lines it would need to have continuity with the "70's" line and transfer through the earth to the "1981" line. There are two locations where the two lines are in close proximity.

The first possibility is where the 1981 line becomes buried. It would be necessary for the lightning current to travel approximately 1,750 feet along the 70's line and pass through five (5) grounded junction boxes, leave the fifth box and enter the nearest 1981 grounded junction box, which is approximately 200 feet from the fifth 70's grounded junction box. At this point both the 70's and 1981 lines could be energized.

The second possiblity is where 2 to 3 pairs (4 to 6 wires) are bridged between the 70's line and the 1981 line. This connection was done to bypass a fault in either the 70's line or the 1981 line. The lightning current would need to travel approximately 2,000 feet along the 70's line and pass through six (6) grounded junction boxes. At this point both lines could be energized.

The total length of line from the lightning source to the Sago Mine is approximately 6,350 feet and would have to pass through 12 grounded junction boxes.

The public telephone distribution boxes at the Sago Mine were also examined. The Verizon phone company had installed a larger box after the January 2, 2006 explosion, but the original box and wiring were still there. The old wiring, coming in from across the Buckhannon River, did not have a ground or messenger wire attached. The only ground wire is inside the distribution box. This wire is attached to a ground lug inside the distribution box and is only tied to the solid copper ground wire coming down the telephone pole. No other wires inside the Distribution Box were attached to the ground lug.

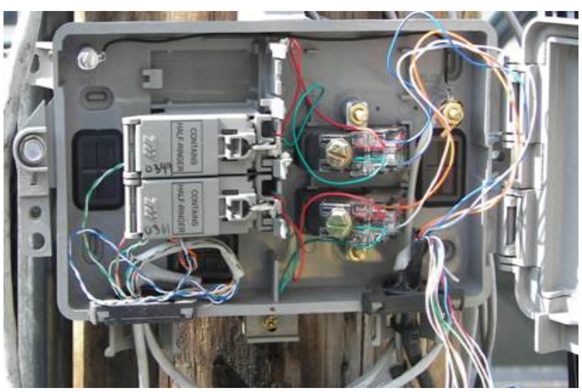


Photo 19: 1 of 2 original phone distribution boxes (still in use). Only the distribution box itself is

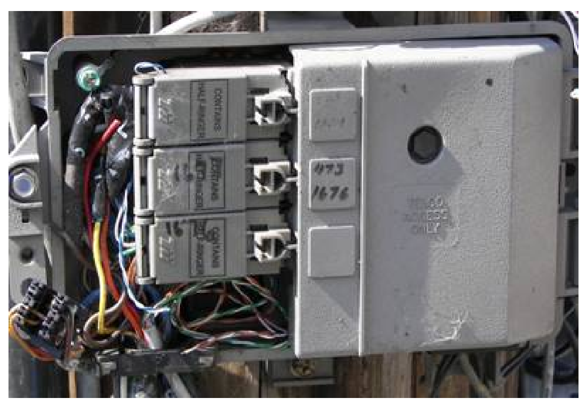


Photo 20: 2nd Original distribution box (still in use)

Photo 21: Messenger wire on new line (not grounded on pole)

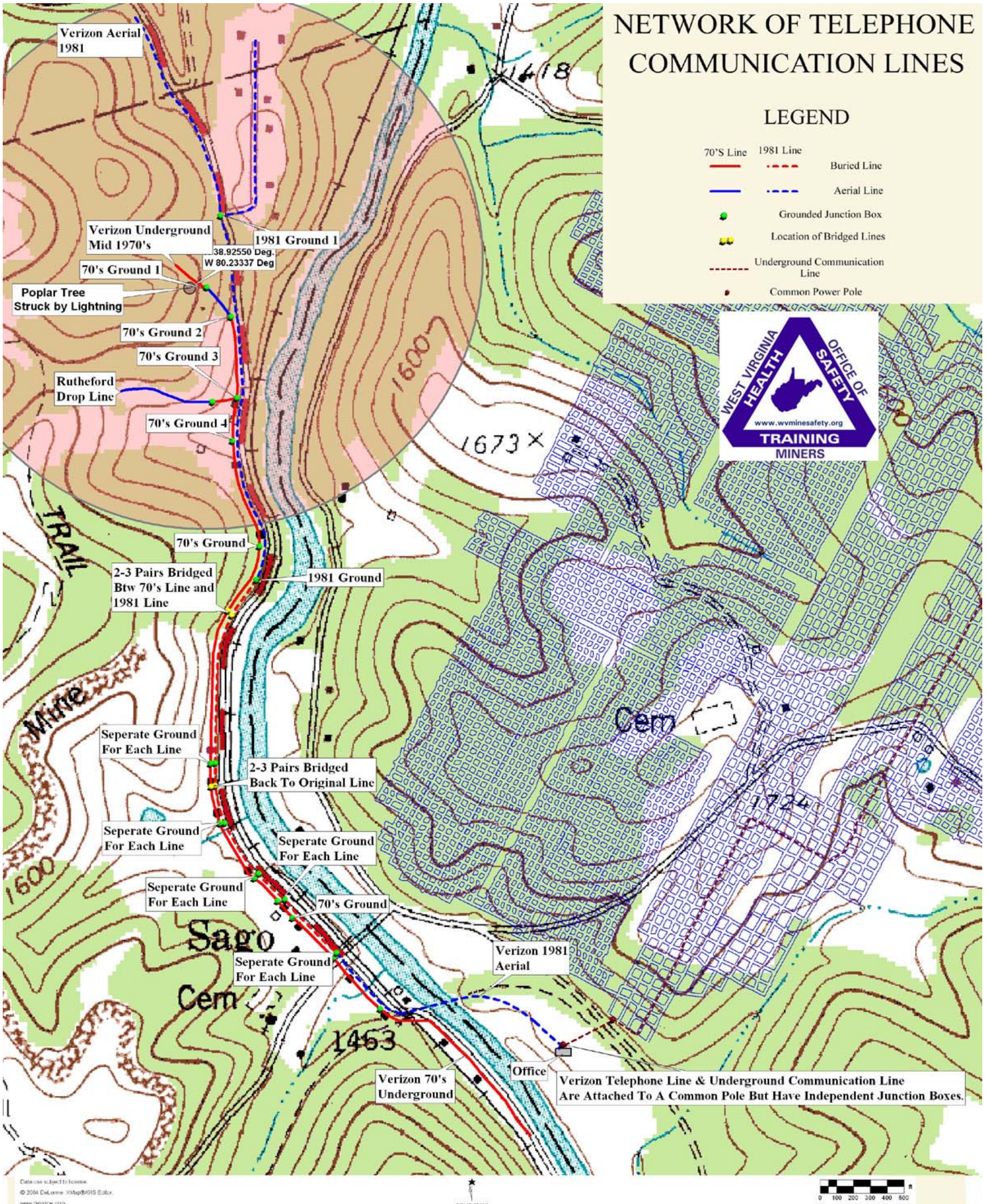
Photo 22: Ground Connection On Pole For Distribution Box

New wiring had been run to the new distribution box by the phone company. This new wiring has a messenger wire attached but it is not connected to a ground on the pole or inside the new distribution box. The only ground wire is inside the distribution box. This wire is attached to a ground lug inside the Distribution Box and was only tied to the solid copper ground wire coming down the telephone pole. No other wires inside the distribution box were grounded.

The telephone service to this mine site was not affected by the lightning strike to the popular tree across the Buckhannon River, on the morning of January 2, 2006, and there is no visual damage inside the phone distribution box. Temporary interference and an acoustic impulse was observed by a Sago worker who was talking on the telephone and he dropped the phone at the same time as a lighting strike.

The Verizon telephone company provided service reports of customers within a three (3) mile radius of the town of Sago, from January 2, 2006 to February 2, 2006. Only one (1) repair was performed. This repair was to the buried 1981 line which does not go to the Sago Mine. This repair was recorded as a broken lead in a junction box.

Another note is that the line that supplies service to Sago Mine also provides service to customers along the Sago road (from the lightning strike to the Sago Mine). The only affected customer was the Rutheford family, and they are on a spur line that branches from the 1981 line (approximately 850 feet of line distance from the lightning strike). Sago Mine's service is provided by the 1970's line. It is highly unlikely that a significant lightning current could travel along the telephone line, enter the mine, and cause a methane ignition without affecting service or causing disruption to the customers between the lightning strike and the Sago mine.



Map 7. Map showing layout of Verizon telephone lines. A larger version of this map is contained in **Appendix 5.5-3**: *Map of Telephone Lines*

5.5-3i Pump cable and wire roof mesh

During the investigation a length of cable with a cable coupler attached to one end was found in the general vicinity of where the explosion appears to have originated. This cable was eventually traced back to a pump that lay submerged in water at the top end (back) of the Old 2nd Left section **(Map 8)**. It was found to be broken in three (3) places over its 1300-ft. length, and was lying with and tangled up among scattered crib blocks and other explosion debris along much of the outby half of its length. The cable lengths are numbered 1 through 4, with the piece terminating at the cable coupler being length #1. Through the work of John Collins, OMHS&T Inspector, and others, these cable lengths were determined to be approximately as follows:

Cable ID	Length	Comments
#1	199.6’	Outby end terminates with cable coupler near spad 4028
#2	188 ‘	Intimately tangled with crib blocks on floor
#3	~93’	Brattice curtain looped around outby end at spad 4089
#4	~812’	Inby end terminates at pump 3 br. inby spad 3713
TOTAL	1293’	

Cable condition at the time of explosion

Although it has not been proven, it is suspected that this 1300’+/- cable may have been intact at the time of the explosion[18]. Reasons for this belief include the following:

- The inby ½ of the pump cable was underwater at the time of the explosion and so escaped damage. Much of this length is still tied by wires to nail anchors in the coal rib or to the wire roof mesh. Similar ties are on the roof, rib, and cable for much of the outby ½ of its length, indicating it could have been similarly hung over much of its total length at the time of the explosion. In addition, the cable lengths one (1) and two (2) were found to be intertwined among crib blocks and brattice in a manner that suggests it was not lying on the floor at the time of the explosion.

- The preliminary results of microscopic examination of the cable ends indicates the breaks were consistent with having failed in tension from pull-apart forces. None of the cable breaks appear to be caused by mechanical cutting tools.

- Visual inspection of the cable shows little evidence of trauma as might be expected if the cable breaks were caused by a piece of mobile face equipment.

- The cable breaks generally occurred in the vicinity of intersections. Blast forces acting perpendicular to a hanging cable by a secondary pressure wave acting through the cross-cuts may have been the mechanism of rupture.

In the presence of a large area of wire roof mesh and wet conditions at the top end of the section, it is not essential that the pump cable be involved to produce the sparks that ignited the methane explosion. Rather, it is just the fact that the explosion appears to have originated close to where the pump cable terminated in a cable coupler that makes it an item of interest. In the absence of a lightning-induced transient on the pump cable, the wire roof mesh itself could have acted as an electric field antenna or been part of a magnetic ground loop that, under the right conditions, could have produced sparks across small gaps and discontinuities in the mesh that ignited the methane.

Voltage differences

As shown in **Map 8**, a large metallic roof mesh overlies the pump cable from the cable coupler to the pump at the top end of the section. That cable is also suspected to have been electrically connected to the wire mesh in the vicinity of the submerged dewater pump at the time of the explosion because the pump control box was tied close to the wire mesh[19] at that time. Therefore the insulated cable ran parallel to and was isolated from the well-grounded wire roof mesh up to the point where it terminated at the cable coupler.

The horizontal pump cable may have brought the ground potential (voltage) of the nearby well casing, the pump, and water (see **Map 8**) into close proximity to a different ground potential (i.e that of the walls, floor, or roof mesh) in the mine void, and if these differences were large enough, they could have produced corona discharges.

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[18] Preliminary results of a forensic analysis on the ends of the cables indicates the breaks were not due to tool cutting but rather were ruptured in tension in a manner consistent with a longitudinal or pull-apart failure. Additional testing is required to determine if equipment or the explosion caused one or more of the ruptures.

An arrangement of a long, insulated cable running parallel to a grounded roof mesh would normally present little cause for concern, however, the unusually intense lightning events such as occurred on the morning of January 2, 2006 and the possibility of *upward or triggered lightning* phenomena, may pose risks to mine safety that have not been fully appreciated

The winter lightning storm of January 2, 2006 was no ordinary storm and the near-simultaneous occurrence of two large positive cloud-to-ground strokes with peak currents of +39 kA and +101 kA, near the Sago mine was extraordinary. As discussed earlier in **Section 5.5-3c** a large lightning flash to ground has the ability to trigger an upward discharge to a tall structure that is several miles from the cloud-to-ground strike point. There are four (4) tall radio antennas on elevated terrain east of Sago mine (see **Map 1**). Upward lightning could have been triggered from one or more of those towers and the current could have coupled into the Sago mine on the large network of gas pipes and wells. Again, upward lightning is not usually detected by the NLDN or other lightning detection networks currently in use.

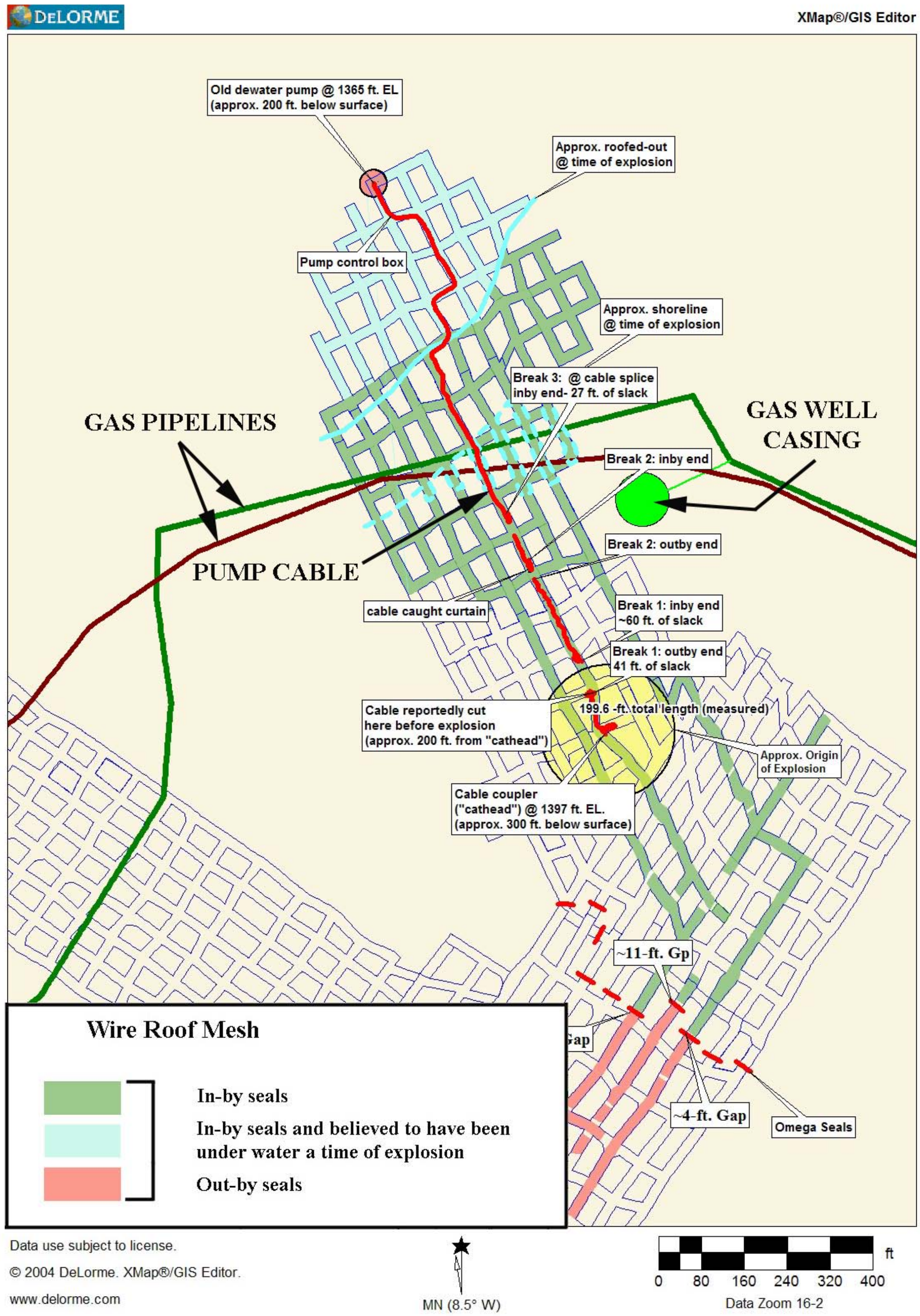
The possibility that the pump cable and/or wire mesh or the nearby gas well and the associated gas pipeline may under unusual conditions produce large voltage differences and corona when they are energized by lightning are possibilities that are still being investigated. Such phenomena are not well-understood but the need to increase our understanding is great. In that respect, the Sago investigation is not complete.

A possible scenario involving the pump cable

A cross-section view of Old 2nd Left Section is given in **Figure 8**. As shown, the rock strata contain sandstone layers that are separated by other layers[20]. Measurements of resistivity are given in **Appendix 5.5-3**: *Geophysical Log for SF 52-06.* Layers of shale and sandy shale are between the sandstone layers, and have comparatively low resistivity. The layer of shale between the coal and the Rider seam appears to generally have the lowest resistivity of all.

[19] The pump control box is the switch box for the pump and separate from the pump. It was submerged below water at the time of the explosion and was reportedly suspended from the wire roof mesh by its retainer chain.

[20] Principally shale and sandy shale



Map 8. Illustration of the arrangement of wire roof mesh to a pump cable and gas well. The gas well is part of a system of approximately 60 wells within a radius of approximately 1.5 miles that are interconnected by a network of gas transmission pipelines at the surface.

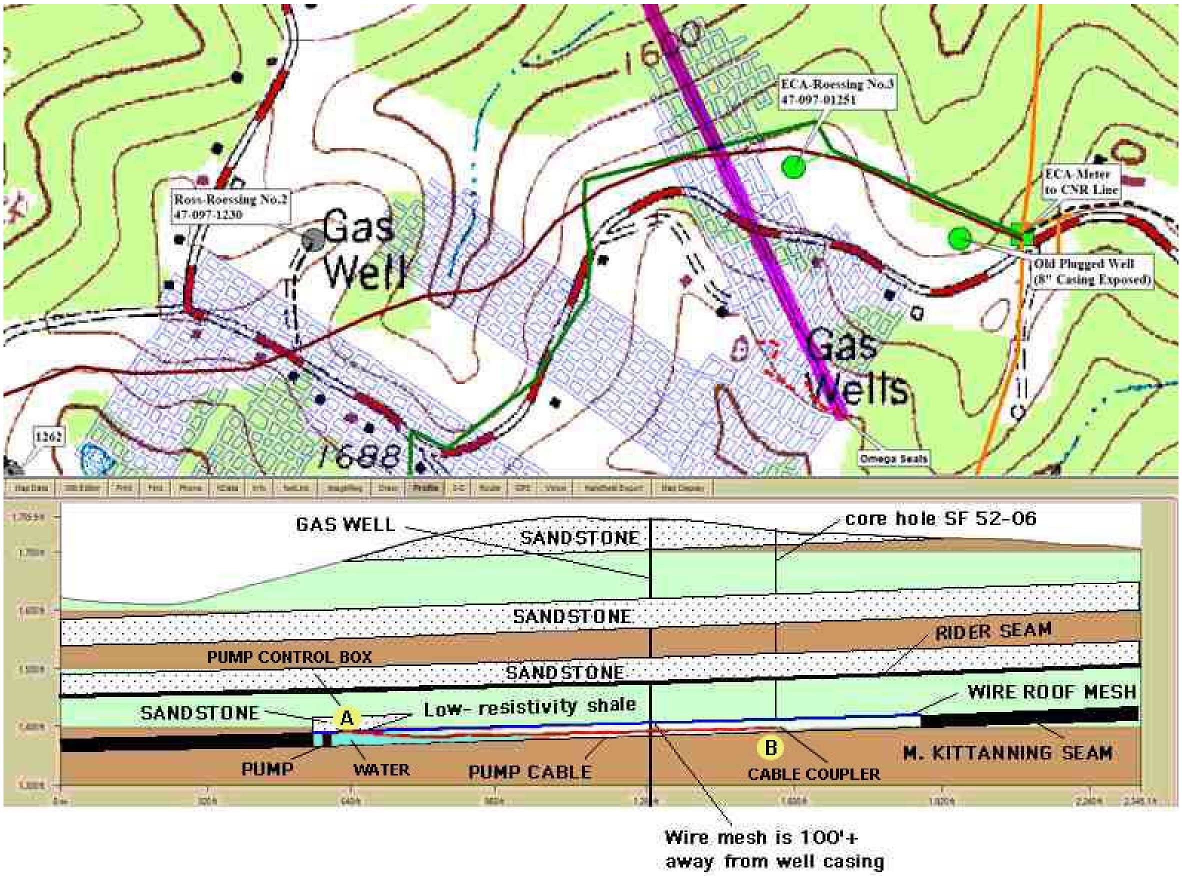


Figure 8. Geologic cross-section through Old 2nd Left Section. E-log to SF 52-06 shows sandstones are high resistivity. The shale roof is low resistivity. The wire roof mesh is bolted to this shale. The pump cable is insulated from the wire roof mesh except at the pump control box.

A local channel sandstone has replaced the shale roof at location "A," and at this location a pump control box connects that cable to a submersible pump. The pump control box was tied to the wire roof mesh at this location. The channel sandstone at "A" produces considerable water, and at the time of the explosion the pump, the pump control box, and the wire mesh at location "A" were underwater. Because the pump control box does not have a waterproof gasket, it was full of mine water and thus the pump cable was probably electrically connected to the wire mesh at "A."

The wire roof mesh covers the mine roof extensively between "A" and "B" as a continuous, uninsulated metallic conductor and the insulated pump cable was either suspended from the roof or lying on the floor of the mine. A time-varying magnetic field could have created a potential difference across the gap at "B," in the metallic loop formed by the roof mesh and the cable shield and of course any current flowing through the finite resistivity of the ground could have created potential differences between the floor, the vertical rock faces, and the roof mesh.

The next step

The region of the Sago Mine will continue to experience lightning and as the winter season approaches it is recommended that we install a number of FSD circuits (see **Figure 9**) within Old 2nd Left Section and at other points in Sago Mine in order to measure the transient voltages and currents that appear underground when there is lightning in the area. Due to the intensive investigations that have taken place at Sago during the past 11 months, we now know more about the arrangement of metallic structures at the surface and underground at Sago and will, hopefully, soon be able to supplement that information with a model of how the electromagnetic energy from lightning penetrated from the surface into the Sago mine[21]. If we can monitor and detect transient currents and voltages from future lightning activity we may be able to correlate them to specific types of lightning and field conditions. This is the first step in developing protective measures to guard against similarly destructive lightning accidents in the future.

The chances of obtaining positive lightning in the Sago area during the winter are as good or better than other geographical locations in the U.S. It is recommended that such a study be implemented at the Sago mine. The types of device that are proposed for monitors are available, inexpensive, and require very little maintenance. They could be left underground, unattended, and will monitor for any current and voltage surges continuously. When a surge is detected, the monitor will shut down and record the time until it is reset. The devices merely need to be checked periodically. By correlating readings of the lightning transient underground, to lightning detected on the surface, we will be in a good position to understanding how lightning entered this mine.

[21] The results of preliminary tests performed for MSHA by Sandia National Labs measuring direct and indirect electric field coupling from the surface to the underground are not yet available to OMHS&T

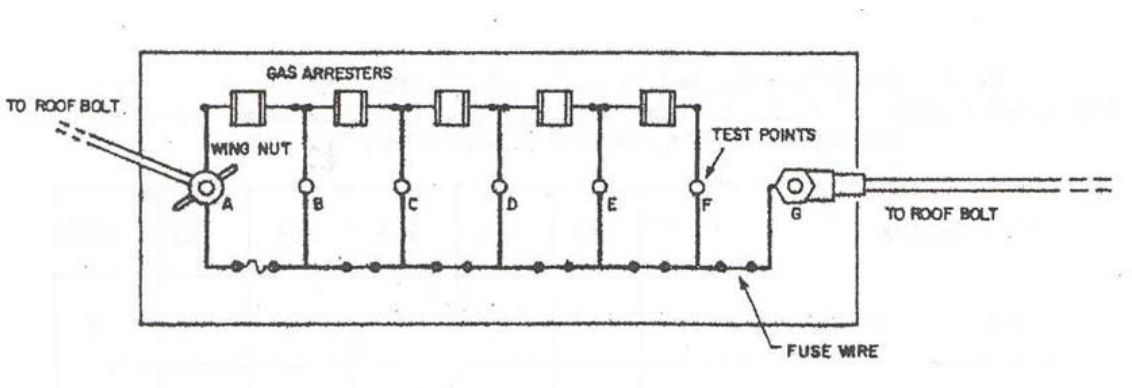


Figure 9. Schematic diagram of the fuse surge detector (FSD) for monitoring of transient currents underground. The FSD comprises six fusable wires in series, with gas arrestors in parallel to five of the six fuses (the electronic circuit is not shown)[22].

[22] H.J. Geldenhuys; Further Progress on Research into Lightning-related incidents in shallow South African Coal Mines, Proceedings of the 23rd International Conf. of Safety in Mines Research Institute, September 11-15, 1989, pp. 1180-1190.

5.6 Self-Contained Self Rescuers (SCSRs)

5.6-1 Breathing Hazards Following an Explosion

5.6-2 SCSR Background

5.6-3 Miner Statements Regarding SCSR Performance

5.6-4 SCSR Training

5.6 Self-Contained Self-Rescuers (SCSRs)

We now know that the miners at Sago appeared to have responded in accordance with their training. Most donned their self-contained self-rescuers (SCSRs). They attempted escape. When all else failed, they barricaded and attempted to alert those on the surface. We may never know exactly what happened on 2nd-left or their experience with their SCSRs but we must learn from what we know.

- Currently acceptable training does not provide miners with sufficient knowledge to make decisions when confronted by unexpected situations.
- Operators, miners, and inspectors need to ensure that SCSRs are treated as the life saving devices that they are.
- Miners need more emergency breathing options to encourage escape and provide protection when barricading.

The function of the SCSR is to provide breathable air while isolating the miner from hazardous gases following a fire or explosion. The miners at Sago were taught to don their SCSRs at the first sign of a problem, "They tell you to put your --- in case of a fire or an explosion put your rescuer on, get everybody in one spot and head for the outside. And they say if escape is cut off, then you barricade on last resort." noted mine examiner Ronald Grall.[1]

When asked if the 2nd-left crew felt like there was no way out, Randal L. McCloy replied "Yeah. Well, because there really wasn't. I mean, there was just no way of doing anything that you wanted to do as far as getting out. Anything that led you to point A, to point B, no, it just couldn't work.

[1] Starting on page 130 of the statement under oath of Ronald Grall

All of our options were diminished to nothing”. In addition to encountering increasingly dense smoke he noted escape was blocked by “…whatever had fallen to block the track.”[2]

If reported problems with SCSRs had a bearing on the deaths of the Sago miners it is not known. One of those that perished suffered significant injuries during the explosion and could not have donned his SCSR. The eleven miners who perished in the 2nd-left barricade were probably exposed to a hazardous atmosphere for a medically significant period prior to donning their SCSRs, were exposed to a hazardous atmosphere when they took the mouthpieces out to talk or work, and were exposed to a hazardous atmosphere in the barricade after their SCSRs were no longer able to produce oxygen. The significance of such exposures was not given enough emphasis in training materials provided by the NIOSH, MSHA, or the manufacturer. These training materials were used by trainers throughout the industry. While testimony by survivors indicates an awareness of the risk posed by such exposure, the medical consequences were less understood both in their descriptions and their actions. Those that perished in the 2nd-left barricade did so in an atmosphere that had sufficient oxygen to sustain life but also contained toxic levels of carbon monoxide.

While directly in the path of the blast, the miners from the 1st-left section were further away. Like the 2nd-left crew they survived the initial blast and moved quickly to attempt escape. They did not don their SCSRs at one time, but rather on an ad hoc basis. Of the thirteen miners on the 1st-left section mantrip when the blast hit, only six actually donned their SCSRs and those at different points during their escape. These miners were in smoke so dense that they could not see their feet, they could hear their handheld gas detectors alarming yet seven chose not to don. The 2nd-left crew appears to have donned as a group indicating an organized escape effort. As with the 1st-left crew they waited. However, they waited longer and in potentially higher concentrations of toxic gases. Part of the answer as to why the miners waited may lie in their perception of the challenges they faced. Paul Avington of the 1st-left crew explained that he delayed donning because, “…we've been more or less told that these rescuers last one hour … I thought, well, I might have to walk out of here. I keep hearing them telling me it takes two hours to walk out of there. So

[2] From statement under oath by Randal L. McCloy June 19, 2006

what I'm doing is saving mine, and trying to go as far as I can."[3] Additionally, those that entered the mine in the first response also chose not to don their SCSRs even though they were often in smoke and their detectors were indicating high carbon monoxide.

5.6- 1 Breathing Hazards Following an Explosion

In a mine explosion the fuel, methane and/or coal dust, combine with oxygen (O) to produce heat and carbon dioxide (CO_2). Typical air has about 21 percent oxygen and as the oxygen is consumed in the explosion insufficient oxygen remains to create only CO_2 and the reaction begins to produce carbon monoxide (CO) until either the fuel or oxygen is depleted. This happened very quickly, on the order of 0.001 second or less. The result is an atmosphere of nitrogen and some oxygen mixed with carbon dioxide, carbon monoxide and trace amounts of other combustion byproducts with possibly some un-combusted methane.

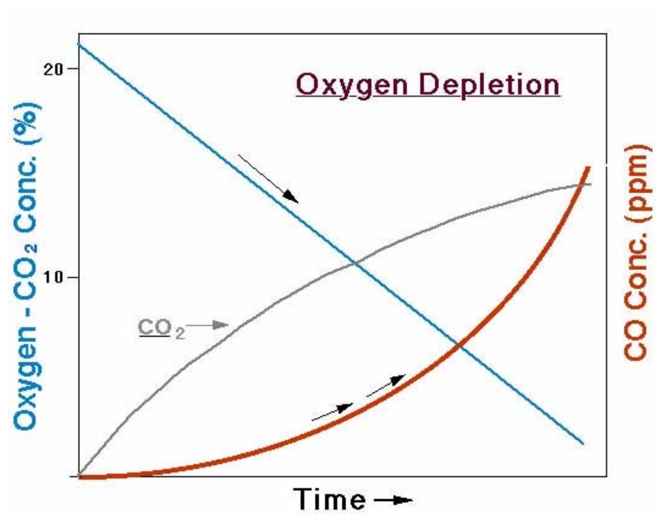
Predominates at 21 percent oxygen...

$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + \text{energy}$

Predominates at 16 percent oxygen...

$CH_4 + 1.5\,O_2 \rightarrow CO + 2\,H_2O + \text{energy}$

In the aftermath of an explosion four gases are of primary concern to those that survive; oxygen, methane, carbon dioxide, and carbon monoxide.



Oxygen is a critical chemical required by our bodies in generating the energy needed by our cells. State and Federal regulations require that oxygen levels be maintained above 19.5 percent in all operating sections of a mine. This value, 19.5 percent oxygen was established on the basis of adverse physiological effects of insufficient oxygen[4]. The medical term for insufficient oxygen is

[3] From statement under oath by Arnett Perry, February 14, 2006 starting page 38

[4] While MSHA discusses a level of 16 percent oxygen in PIB96-19 as "life threatening", multiple federal regulation stipulate 19.5 percent as the minimum oxygen concentration, i.e.: 42CFR84.2(y) defines an "oxygen-deficient atmosphere" as an atmosphere which contains an oxygen partial pressure of less than 148 millimeters of mercury (19.5 percent by volume at sea level). This value is also used by OSHA in 29CFR1910.134(b). NIOSH Publication

hypoxia with symptoms that include fatigue, lassitude[5], somnolence[6], dizziness, headache, breathlessness, and euphoria. Intellectual impairment is an early sign and makes it difficult for individuals to comprehend their degree of disability. Thinking is slow. Calculations are unreliable. Memory is faulty. Judgment is poor. Reaction time is delayed.

Methane is a light, colorless, gaseous, inflammable hydrocarbon that is a natural product of the process of forming coal. Often referred to by its chemical symbol, CH_4, it is naturally liberated from coal as the hydrogen is slowly released as coal changes from peat to anthracite. Methane is nontoxic, however, can displace all or part of the atmosphere in a confined space. With only five percent displacement, methane produces an atmosphere which, while adequate for respiration, can explode violently. By contrast, with twenty percent displacement, methane will not burn or explode, but it will asphyxiate an unprotected miner within about five minutes from lack of oxygen.

Carbon dioxide is a colorless, odorless, incombustible gas formed during respiration, combustion, and organic decomposition. It is often referred to by its chemical symbol CO_2. State and federal rules have assigned a maximum level for carbon dioxide of 5,000 ppm or 0.5 percent. The concentration of carbon dioxide must be over about 2.0 percent (20,000 ppm) before most people can sense its presence. Above 2.0 percent, carbon dioxide may cause a feeling of heaviness in the chest and/or more frequent and deeper breathing. As the carbon dioxide concentration climbs above a few percent, the concentration of oxygen in the air inhaled begins to be affected.[7] At six percent carbon dioxide, for instance, the concentration of oxygen in air has decreased from 20.96 to 19.9 percent.

No. 2005-100 notes that "The minimum requirement of 19.5 percent oxygen at sea level provides an adequate amount of oxygen for most work assignments and includes a safety factor. The safety factor is needed because oxygen-deficient atmospheres offer little warning of the danger, and the continuous measurement of an oxygen-deficient atmosphere is difficult. At oxygen concentrations below 16 percent at sea level, decreased mental effectiveness, visual acuity, and muscular coordination occur. At oxygen concentrations below 10 percent, loss of consciousness may occur, and below 6 percent oxygen, death will result. Often only mild subjective changes are noted by individuals exposed to low concentrations of oxygen, and collapse can occur without warning."

[5] state of exhaustion

[6] drowsiness, sleepiness

[7] Martin, T.G., and J.L. Burgess. *Dreisbach's Handbook of Poisoning.* 13th ed. Pearl River, NY: Parthenon Publishing, 2001.

Carbon monoxide (CO) is a colorless, odorless, tasteless gas that is toxic. Carbon monoxide, sometimes called coal gas, has been known as a toxic substance since the third century B.C. It was used for executions in early Rome. Today it is the leading cause of accidental poisoning in the United States. According to the National Institute for Occupational Safety and Health[8], 1,500 Americans die each year from accidental exposure to CO, and another 2,300 from intentional exposure (suicide). An additional 10,000 people seek medical attention after exposure to carbon monoxide. It is an asphyxiant[9]. When inhaled, carbon monoxide quickly binds with hemoglobin in the blood stream with an affinity 200 to 250 times greater than that of oxygen to from carbooxyhemoglobin[10] (COHb)[11]. The result is a decrease in blood oxygen carrying ability of the blood and the onset of acute hypoxic symptoms (primarily neurologic[12] and cardiac). A person suffering from carbon monoxide intoxication may first experience euphoria, then headache, followed by nausea and possibly vomiting as the concentration of carbooxyhemoglobin (cells affected by carbon monoxide) in the blood increases.[13] To protect miners, MSHA sets the limit for carbon monoxide in 30 CFR Part 75.322 [14] at 50 ppm average over a 10 hour shift with no more than a 15 minute concentration of up to 400 ppm.

It was carbon monoxide that posed the greatest danger following the Sago explosion. There are no readings or reports of oxygen concentrations low enough to have been life threatening. While smoke and dust were discussed by all the survivors, it was this odorless gas that ultimately inflicted the harm.

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[8] Unintentional Non-Fire-Related Carbon Monoxide Exposures — United States, 2001–2003 - http://www.cdc.gov/od/oc/media/pressrel/fs050120.htm

[9] an agent that causes asphyxia, for example, a toxic gas

[10] Hemoglobin that has carbon monoxide instead of the normal oxygen bound to it.

[11] Hardy KR, Thom SR. Pathophysiology and treatment of carbon monoxide poisoning. J Clin Toxicol 1994;32(6):613-29

[12] The branch of medicine that deals with the structure and function of the nervous system and the treatment of the diseases and disorders that affect it

[13] Haddad, Lester M. "Acute Poisoning" Cecil Textbook of Medicine, edited by Lee Goldman, and J. Claude Bennett. 21st ed. Philadelphia: W.B. Saunders, 2000, pp. 515-522.

[14] Concentrations of noxious or poisonous gases, other than carbon dioxide, shall not exceed the threshold limit values for time weighted averages (TLV-TWA) as specified and applied by the American Conference of Governmental Industrial Hygienists in "Threshold Limit Values for Substance in Workroom Air" (1972) Detectors or laboratory analysis of mine air samples shall be used to determine the concentrations of harmful, noxious, or poisonous gases. The ACGIH has a TLV-TWA of 50 ppm with a TLV-STEL of 400 ppm. (Threshold Limit Value, Short Term Exposure Limit, is the maximum concentration permitted for a continuous 15-minute exposure period. There may be

The primary protection available to miners is their SCSR.

5.6-2 SCSR Background

It is important to understand how SCSRs work and how units recovered after an accident are examined. A total of seventeen SCSRs used by Sago miners were found in the mine during the investigation. (Others found were brought in my rescue teams and used to evacuate Mr. McCloy) Their locations were marked on recovery maps and plotted to understand their positions in the mine along with their relationship to victims and other items. They were then transferred to the custody of federal investigators[15] and examined.

The examination process includes inspection of the hoses and exterior parts for any damage. Next the sealed stainless steel canister is cut open and the condition of the chemical bed examined for signs of reaction. Based upon expertise in examining previous SCSRs, an estimate is made of the amount of the chemical that has reacted.[16] Then the units are taken to the manufacturer's laboratory where a representative sample of the chemical is reacted to produce gas. The volume of the gas produced is compared to the volume produced for the same amount of chemical for deployed SCSRs and a percentage is calculated.[17] Both values are provided to the investigators.

The CSE SR-100 is a belt-wearable chemical based self-contained self-rescuer that uses potassium superoxide (KO_2), a yellow solid which reacts readily with carbon dioxide and water to produce oxygen. The SR-100 consists of a stainless steel canister with an opening

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a maximum of four such periods per day, with at least 60 minutes between exposure periods, and provided the daily TLV-TWA is not exceeded)

[15] MSHA took custody of the SCSRs and placed them in sealed plastic bags for transfer to NIOSH's National Personal Protection Technology Laboratory in Bruceton PA

[16] NIOSH "Investigation Protocol for Self-Contained Self-Regulators (SCSRs) Removed from the Sago Mine Disaster", 24 March 2006

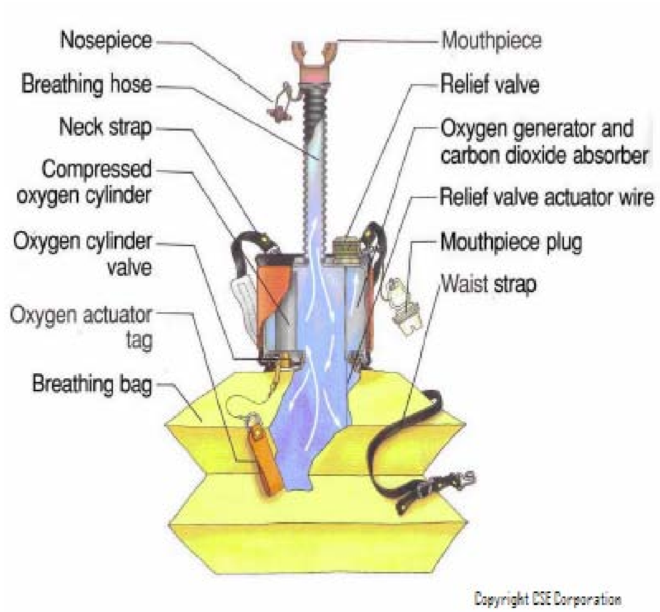
[17] Conversations with Sam Shearer, Chairman, and Scott Shearer, President, CSE Corp April 2006. CSE's stated their preferred method for recovered unit examination would be to first run an air flow measurement through the bed to determine the degree of chemical bed solidification then open the canister to examine the particles, then conduct a chemical analysis of the material – Randall Harris OMHS&T consultant

for a breathing hose on one end and a breathing bag on the other. The breathing bag serves as a mixing chamber where exhaled breath is mixed with produced oxygen prior to inhalation.

The chemical SCSR uses the carbon dioxide and water vapor produced by the body in reactions with the potassium superoxide and lithium hydroxide to reduce carbon dioxide and generate oxygen.

Component	Atmospheric Air %	Exhaled Air %
Nitrogen	78.62	74.9
Oxygen	20.85	15.3
Carbon Dioxide	0.03	3.6
Water vapor	0.5	6.2

Exhaled air passes through the mouthpiece into the canister where some of the carbon dioxide is removed by the lithium hydroxide and the rest through a reaction with the water vapor and the potassium superoxide to produce oxygen. The oxygen rich air passes through to the breathing bag where it mixes with either the pure oxygen from the oxygen cylinder or previous air breathed through the canister. On inhalation air from the breathing bag passes back through the chemicals in the canister where it is further enhanced by additional scrubbing of carbon dioxide as it and remaining water vapor create additional oxygen.



The purpose of the compressed oxygen cylinder is to inflate the breathing bag with oxygen as an initial reserve while the chemical reaction begins. It plays no role in starting the chemical reaction. The chemical reaction begins with the introduction of exhaled breaths that provide the carbon dioxide and water vapor needed. If the oxygen cylinders do not inflate the breathing bag, either because they have leaked all their oxygen or because the user removed the mouth plug prior to pulling the tag, the chemical reaction can be started by expelling enough breaths to fill the bag using the mine atmosphere. When the bag is filled, the miner is trained to start breathing normally. As the carbon dioxide and water vapor react with the potassium superoxide the oxygen concentration will increase. The time before oxygen concentrations reach the 19.5 percent value defined as oxygen deficient[18] will vary. Tests by OMHS&T and NIOSH using automated breathing simulators indicate that value may exceed seven minutes if the compressed oxygen cylinder fails.[19]

Because the SR-100 is a closed circuit breathing device, any toxic gases introduced into it remain there. They would have recirculated between the lungs and the device until the body fully absorbed them.

As potassium superoxide reacts with carbon dioxide and water vapor at the surface of the particle it produces potassium bicarbonate ($KHCO_3$) which is white crystalline compound.

$$4\ KO_2 + 2\ H_2O \rightarrow 4\ KOH + 3\ O_2 + \text{heat}$$
$$2\ KOH + CO_2 \rightarrow K_2CO_3 + H_2O + \text{heat}$$
$$K_2CO_3 + CO_2 + H_2O \rightarrow 2\ KHCO_3 + \text{heat}$$

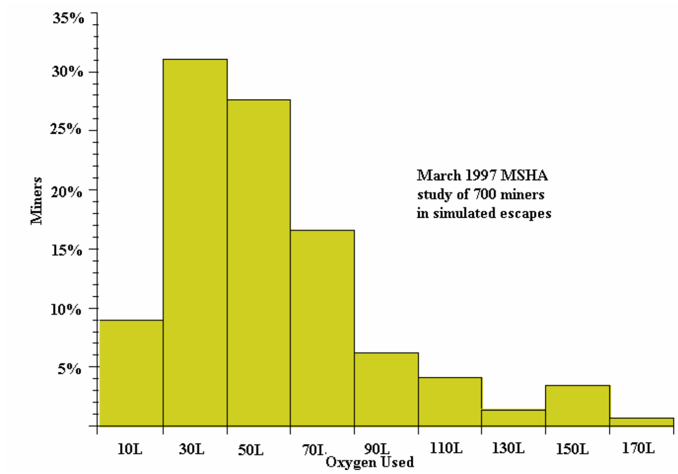
The SR-100 also utilizes a proprietary chemical catalyst that works with these reactions to ensure complete reaction of available potassium superoxide.

While the oxygen generation reaction is progressing, there is enough heat being generated by the reaction that the potassium bicarbonate remains a liquid. If the user stops breathing once the reaction has started, the lack of carbon dioxide and water vapor reduces the temperature in the canister and the potassium bicarbonate solidifies, forming a hard coating around any of the un-reacted portions of potassium superoxide particle. This coating tends to protect the

[18] 42CFR84.2(y) defines an “oxygen-deficient atmosphere” as an atmosphere which contains an oxygen partial pressure of less than 148 millimeters of mercury (19.5 percent by volume at sea level)
[19] NIOSH field study data and OMHS&T inspector’s SCSR testing both 2006

particle, thus making it difficult to re-start a chemical based SCSR once it has been allowed to cool from lack of use.

The potassium superoxide (KO_2) reaction is controlled by the volume of exhaled breath blown into the canister. Breathing hard and rapidly moves more air in and out, thus more carbon dioxide and water vapor is moved through the canister. Trying to push or pull a volume of air through the chemical bed greater than it was designed to handle will generate breathing resistance. Too much water vapor and carbon dioxide will cause the heat generated to be such that the air pathways will become blocked by particles fused from reaction by-products. This channeling of air open pathways will isolate the surface of some potassium superoxide particles from the moisture rich air inhibiting the production of oxygen.



The federal approval of the SR-100 is based upon procedures contained in Title 42 of the Code of Federal Regulations Part 84. The approvals are based on a SCSR's ability to produce oxygen and remove carbon dioxide over a specified set of human exercise levels for a time period stipulated by the manufacturer in addition to several other ergonomic issues. The manufacturer stipulates the duration of the test in their application. In the case of the SR-100, it was subjected to the requested one hour testing protocol. The one-hour rating simply means that an SCSR can repeatedly demonstrate the ability to pass this test. Use at exercise rates different than those used in the approval test or by individuals whose physical conditioning varies significantly from those stipulated in the Federal regulations will produce different results.

Because it is unknown how hard or how rapidly the 2nd-left miners were breathing when they donned their SCSRs, how many times and for how long SCSRs sat idle, or how breathing rates changed while in the barricade, it is impossible to predict how long the SCSRs should have lasted. If breathing very hard and very rapidly at the time donned, it is possible SCSRs reaction rates would have been high resulting in higher breathing resistance not only from higher than design volumes but increased reactions rates would have sped the chemical reaction, prematurely obstructing air flow and limiting ability to produce oxygen. If the SCSR is allowed to cool sufficiently, the potassium bicarbonate shell could solidify reducing oxygen potential.

The visual examination of recovered SCSRs was performed by federal investigators, followed by a chemical examination conducted by the manufacturer and supervised by federal examiners. The visual examination produces a subjective estimate of spent potassium superoxide based upon comparing the approximate quantity that is unreacted (yellow) to those that have been reacted (pale yellow or white-coated with white potassium bicarbonate).

The chemical examination grinds the entire recovered chemical into a homogeneous batch and then combines a portion of the batch with a liquid catalyst in a reaction that releases all the oxygen. The results are compared to the oxygen produced by the same amount of new chemical and a percentage calculated.

Either process may indeed accurately depict the oxygen producing potential of the chemical outside the canister. Such a test does not, however, take into account any reduction in air flow as a result of particle fusing of the chemicals in the canister or rendering of particles as unavailable due to coating and thus may not provide a meaningful representation of the miners' experience with the assembled device. While reported in this discussion these values confirm the initiation of the chemical reaction but their use as a forensic tool beyond that is limited. Still the number of 2nd-left SCSRs which did not demonstrate significant levels of spent potassium superoxide is perplexing.

In January 2006 there was no state requirement that a consolidated record of SCSR inspections be kept and no state or federal requirement that there be the ability to trace a unit to an individual miner. The records kept at the Sago mine regarding their SCSRs do not provide all the information necessary to correlate serial numbers and individuals to whom assigned to the physical evidence. Several of the miners underground on January 2, 2006 had recently transferred from other mines. Some of these individuals brought their SCSRs from those mines further complicating the recordkeeping. At least one SCSR deployed by the 2nd-left crew had exceeded its 10-year service life in August 2005. This was not recognized when most of the SCSRs at the mine were inspected in November 2005.

Under manufacturer's directions, miners should inspect their SCSRs daily for signs of physical damage. At least one SCSR was unable to be removed from the fabric holster because it was glued to it by block-bond adhesive.

The SR-100 is approved as a belt-wearable device. The testing done during the federal approval process to ensure the devices survivability assumes that the units are in their approved holster on the miners' belts. Several of the holsters were found on the ground near the covers that were removed when the SCSRs were donned. Of the twenty-four recovered SCSRs, federal examiners found seven had impact dents in the stainless steel canisters that may not have been detectable in routine inspections. These findings imply that the SCSRs were carried by miners in their hands or placed loose on equipment rather than on their belts. If the units were subjected to physical impacts greater than those designed against, that could subject internal components to damage that could not be observed under typical inspections.

The Sago mine provided SCSRs for each miner but no checks were in place to ensure that miners did not pick up the wrong unit in the bathhouse, at the dinner hole, or after turning the units in for 90-day inspections. It would not be unusual that every miner underground would have an SCSR but not necessarily the one assigned in the company logs.

When not underground, miners would leave their belts and gear in the bathhouse. Lockers were provided for personal items and clean clothes. Boots and belts would be hoisted, that is elevated toward the top of the room to dry. It is not known if any of the individuals took their gear with them in personal vehicles. Since very few of the SR-100's used at the mine of January 2, 2006 were manufactured after August 2004 when heat damages detectors were added, there is no way of determining heat related damage other than external evaluation. The principal damage caused by heat is to rubber parts inside the unit such as hoses and the breathing bag. The examination of recovered SCSRs revealed no heat related damage to hoses or bags beyond minor deformation and discoloring. There is indication that the rubber gaskets between the canister and the covers may have been impacted represented by binding of the rubber to the parts resulting in difficulty in removing covers.

5.6-3 Miner Statements Regarding SCSR Performance

A total of 33 persons were underground[20] after the explosion for periods of time and exposed to the hazardous gases that resulted. Of these, fifteen donned SCSRs[21] that operated adequately, fourteen choose not to don their SCSRs[22], four SCSRs were reported as not functioning properly[23], and one suffered injuries such that he could not have donned his SCSR.

Interviews were conducted with all 21 surviving miners. These are the experts in what happened. The following summarizes the testimony from these interviews with respect to SCSRs, including their experience donning and breathing through them, their observations of other miners using the devices, and their SCSR training. Where appropriate any available results of federal recovered SCSR examinations are included in the discussion.

5.6-3a Miners who DID NOT DON their SCSRs

Fourteen of the 21 miners interviewed DID NOT DON their SCSRs after the explosion occurred. Their reasons provide an insight into how miners with similar levels of experience would respond in the face of an explosion. These individuals were not new to mining, many

[20] The 2nd-left mantrip carried twelve, the 1st-left mantrip carried fifteen, one remained underground from the pre-shift examination, one walked in for his shift, and four entered in the initial attempt to assess the situation and save the first- and 2nd-left crews

[21] From Statements under oath – Denver Anderson, Alva Bennett, James Bennett, George Hamner, Eric Hess, Hoy Keith, David Lewis, Randal McCloy, Arnett Roger Perry, Harley Joe Ryan, Alton Wamsley, Fred Ware, Jackie Weaver, and Marshal Winans

[22] From statements under oath – Paul Avington, John Nelson Boni, John Patrick Boni, Gary Carpenter, Ron Grall, Randall Helmick, Vernon Keith Hofer, James Jamison. Owen Jones, Gary Rowan, James Allen Schoonover, Christopher Tenny, Jeffrey Keith Toler, and Denver Wilfong

[23] From statements under oath – Thomas Anderson, Jerry Groves, Jesse Jones, and Martin Toler Jr

had more than 20 years experience. They include certified mine foremen and certified trainers who would have been exposed to the knowledge that hazardous gases posed a threat greater than the smoke in their training.[24] Ironically those who did protect themselves by donning their SCSRs often credited these very people with teaching them that they should don immediately.

"The 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. And Paul Avington asked me if we should go ahead and put them on. I said, not yet, because I was trying to get the fresh air" said Ronald Grall whose reasons were typical[25]. In retrospect he added "We should have probably put them on."

The opinions of those in small groups played a role in the decisions of several miners not to don their SCSRs. For example when asked why he did not don his SCSR Gary Rowan responded "Well, I don't know. I just --- I remember asking Ron, I said, do you think we better stop and put our rescuers on. And he said, no, let's keep going. So I --- we just kept going, didn't put it on." [26]

Several of the outby crew were far enough from the explosion to not have been affected by the blast. However, even knowing there had been an explosion, they based their decision not to don SCSRs. John Patrick Boni was typical of this group. He said simply "I knew I was in good air" [27]

Others indicated that they were holding it in reserve, not knowing what they might encounter during their escape. "I keep hearing them telling me it takes two hours to walk out of there. So what I'm doing is saving mine, and trying to go as far as I can" remarked Arnett Perry[28].

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[24] From statement under oath by Eric Hess February 14, 2006 starting page 76 Q. In the foremen trainee class have you covered gasses yet? A. Yeah. A lot of gasses
[25] From statement under oath of Ronald Grall January 19, 2006 starting on page 66
[26] From statement under oath of Gary Rowan February 15, 2006 starting on page 33
[27] From statement under oath of John Patrick Boni January 19, 2006 starting on page 43
[28] From statement under oath of Arnett Perry January 26, 2006 starting on page 38

Of those interviewed, several, but not all, were asked if they heard that other miners had problems using the device. Most were not aware of any trouble. One miner said, “I did hear a couple of comments after we were in the intake that they weren’t working. They (unidentified) couldn’t breathe with them on --- a couple comments that these things aren’t working --- they didn’t state as to why, just said they were having trouble breathing with them on.”[29] However, even those who were noted by others as having made such remarks about trouble or were thought by observers to have been having trouble, when directly asked said their SCSRs functioned adequately.

5.6-3b Miners who DONNED their SCSRs

Seventeen miners DONNED their SCSRs. Six of those were in the first left crew; eleven were in the 2nd-left crew. Four of those on the 2nd-left crew were reported as not working properly.

Most miners go through an entire career without donning an SCSR in an emergency. While they are regularly trained in the donning procedure there is always doubt about if they could don the units in an actual emergency. This was best explained by Eric Hess of the 1st-left crew when he said “…it's always been a big question in the back of my head, you know, if you have to put this thing on, do you think you could do it?. And they tell you, you know, it takes approximately 30 seconds to get it on. That's about right. To get that thing broke down and get it and get it working, it doesn't take very long. I mean, at the point of course you're nervous, but you know you've got to get that thing on. If you want to start breathing good air, you've got to get it on. So you know once I got it on and got --- you know, got everything strapped on and got it where it needed to be, you know, a little bit of calmness starts setting in because you know you're breathing and you know you're going to be all right. Or you think you're going to be all right. But at the time, we didn't know what was happening. But just having that thing on and breathing fresh air gives you a little bit of a sense that, you know ---” [30]

[29] From statement under oath of Christopher Tenney January 23, 2006

Some donned as soon as they could like Alton Wamsley "… the smoke was really --- it was really un-breathable. I just tried to take short breaths until I got my rescuer on. As far as I can remember, I'm the first one that put my rescuer on."[31] Others tried walking to the intake first as did Mr. Hess, "Just as soon as we got out of the mantrip and walked down --- like I said, the mantrip was sitting in 50 block four-belt, that's where the switch is. The mantrip was sitting right there at the switch. We got out of the mantrip and went to the first crosscut and we knew that that's where power --- the power shutters were. So we went to the next crosscut back and there was a man door. So we went through the door and noticed that we didn't have any fresh air at that point. So that's when me and Alton Wamsley, that's when we put ours on, just immediately. We both agreed, you know, this is bad. You know, we're breathing --- we don't know what we're breathing, but it's bad, we need to get them on. So that's when we put them on." [32] Mr. Hess said.

Even those that said they had trouble in donning or using their SCSRs stated that they felt that it performed as they thought it would. Denver Anderson said it worked "I heard they get warm, you know, if they were working, and mine got warm. And I heard one of the other guys complaining about his getting pretty warm. Mine didn't get --- I mean, enough, noticeable, you know ---. I breathed with it,"[33] he said.

Four individuals were able to don their SCSRs only with assistance from those that had already donned their units. Two of these had pre-existing health conditions, one was suffering from blast driven dirt in his eyes, and another had block-bond adhesive on his SCSR holster keeping him from opening his unit. This assistance by fellow miners is a trait that has been documented in other accident reports. However, this assistance is only possible because those assisting first donned their SCSRs. The record from previous accidents also contains examples of miners helping others only with all perishing because they did don their SCSR.

5.6-3c Hoy Keith's Experience

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[30] From statement under oath by Eric Hess February 14, 2006 starting on page 41
[31] From statement under oath by Alton Wamsley February 14, 2006 starting on page 31
[32] From statement under oath by Eric Hess February 14, 2006 starting on page 41
[33] From statement under oath by Denver Anderson starting on page 34

Mr. Keith's experience was the most frequently discussed by his fellow miners during their statements. Most related his trouble breathing and some said that they were not sure that his SCSR was functioning. When asked if it was easier to breathe with the unit on, Mr. Hoy stated "I can't say it was, because I had so much of that dust and stuff in my lungs, and stuff like that. You couldn't hardly breathe. When I did get the fresh air, the guy gave me his water jug, and I rinsed my mouth out some. And that helped a lot."[34] Gary Rowan who helped Mr. Keith don his SCSR and stayed with him as he escaped 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. I mean --- but you know, like I said, he was just --- he was panicked pretty bad and he --- I mean, he told us just leave him in there." [35]

5.6-3d Arnett Roger Perry's Experience

Mr. Perry was facing inby on the mantrip when the blast hit. His cap lamp lens was broken by a piece of debris, his hat and safety glasses blown off and his eyes filled with dirt. In addition, Mr. Perry has a prosthetic leg and had difficulty moving on the uneven surface. Harley Joe Ryan assisted him in opening his SCSR and donning. Mr. Perry said that "It didn't [work] at first. I was sucking the bag together, I was breathing so hard because I'm short-winded and I was sucking that bag up in until it sucked --- collapsed. So I breathed into it and blew it way out…" [36] When asked about pulling the activation tag, Mr. Perry said "No, I didn't yank anything that I can recall." If he did not pull the oxygen starter then the performance he encountered is consistent with a cold start as described by the manufacturer.

Examination of the SCSR assigned Mr. Perry indicated that the compressed oxygen cylinder had been activated but there is no way of knowing if it were at the point of donning or later. Additionally there is no way of knowing for certain that the unit assigned Mr. Perry was the unit he donned. Not all the donned SCSRs from 1st-left crew were recovered.

5.6-3e Harley Joe Ryan's Experience

[34] From statement under oath by Hoy Keith January 23, 2006 starting on page 25
[35] From statement under oath by Gary Rowan February 15, 2006 starting page 65
[36] From statement under oath by Arnett Roger Perry January 26, 2006 starting page 49

Mr. Ryan required assistance in donning his SCSR he remembered being "Panicked --- scared --- scared to a point. More panicked I think than anything else due to the fact that I just thought everybody is leaving us, and I was trying to get Doc down out of there and he was --- Doc was a little worse off than I was."[37] Mr. Ryan had his SCSR in his hand trying to pull the tab to release the bands that hold the covers. He said "You just couldn't get the tab off. You couldn't get a hold of it for one thing."[38] Alton Wamsley assisted him getting the bands off "We took the top part of it --- we broke the band, took the top part off. I took my hat off. He threw the band around my --- the strap around my neck. I put my hat back on. He had the nose clips. And as he was putting the nose clips on, I made sure that the mouthpiece wasn't tangled, and I put it in my mouth. And then that's when either him or me, I don't know which, grabbed the bottom and jerked, and we had to jerk a couple, three times to get it to come loose. When it popped loose, he handed me the goggles, and he grabbed the cord and popped the rescuer open,"[39] he said.

When asked if he was able to breathe with it normally he responded "Yes". He notes that later while in the intake "the bottom part of my bag collapsed"[40] The breathing bag of the CSE SR-100 is actually two bags interconnected. Under normal ventilation only one 'bag' would be fully inflated. Both bags will inflate when the user is breathing near the capacity of the unit. Mr. Ryan did comment on problems using the mouthpiece since he does not have teeth "I kept it in my mouth. I had trouble keeping it in, but I kept it in. You had to clamp on it," [41] he said.

Mr. Ryan's SCSR was recovered and tested by federal examiners. The visual examination indicated 40-50 percent spent. Mr. Ryan indicated that he donned his SCSR as quickly as possible after the 6:30 a.m. explosion and did not remove it until 7:30 a.m. The mouthpiece of his SCSR was partly blocked by foreign matter, believed to be snuff.

5.6-3f Denver (Doc) Anderson's Experience

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[37] From statement under oath by Harley Joe Ryan January 26, 2006
[38] From statement under oath by Harley Joe Ryan January 26, 2006 starting page 55
[39] From statement under oath by Harley Joe Ryan January 26, 2006 starting page 55
[40] From statement under oath by Harley Joe Ryan January 26, 2006 starting page 58
[41] From statement under oath by Harley Joe Ryan January 26, 2006 starting page 57

Mr. Anderson had difficultly removing his SCSR from its fabric holster. Eric Hess said, "He's like the utility man, so he does a lot of stoppings and does…a lot of the B-Bond and plastering, and his rescuer had B-Bond 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. And I pulled the strap off, the metal band off for him and got it broke down, and then gave it to him and he got it --- he got it put on and got it working."[42] According to the manufacturer, in order to properly conduct the required daily inspection of the SR-100, the miner has to remove the unit from its cloth holster.[43]

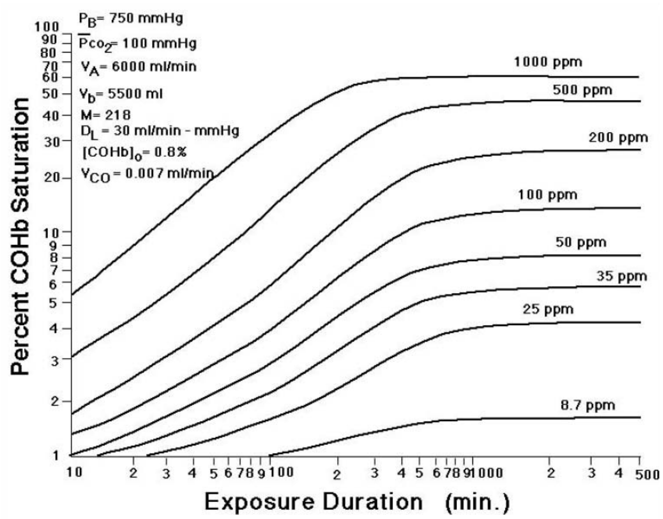
5.6-3g 2nd-left's Experience

The 2nd-left story is told by Randal L. McCloy and by the physical evidence. The crew was near the face when the blast occurred. They were engulfed by a cloud of dust, smoke and, most likely, toxic gases. Some if not all of the crew moved back to the mantrip and attempted to escape. Finding the track blocked somewhere short of the main, they reversed to approximately 10-block six-belt where the mantrip was abandoned. The crew then made its way inby and at the crosscut near 12-block six-belt on the intake entry all donned their SCSRs. It is difficult to determine how long that would have been after the blast. Based upon the distances involved and the time to load and unload the mantrip, it was likely no less than 20 minutes nor longer than 45 minutes.

During that time they would have been exposed to high levels of carbon monoxide, carbon dioxide, smoke, dust and possibly low oxygen. When the borehole was drilled into the 2nd-left section approximately 24 hours later the levels were 1,280 ppm carbon monoxide with oxygen levels of 20.3 percent and methane at 0.4 percent. Almost 40 hours after the event when the rescue teams reached the point where the SCSRs had been donned, the carbon monoxide was 450 ppm, oxygen was over 20.3 percent, and methane at 0.2 percent[44]. It is

[42] From statement under oath by Eric Hess February 14, 2006 starting on page 41
[43] The CSE manual discusses that the pouch must be loose fitting and the SCSR must be easily removed. This and the directions for examining the case and seals require that unit be removed from the cloth holster daily.
[44] Statement under oath of Christopher Lilly March 23, 2006 starting on page 48

possible that the value at the time prior to donning SCSRs was above this 1,280 ppm value but how high may never be known.



Log-log plot of carbon monoxide uptake by humans from very low ambient carbon monoxide concentrations as computed from the Coburn-Forster-Kane equation. [45]

Levels above 1,280 ppm even for short periods of time would have caused some physiological affects in those that inhaled it. Inhalation of carbon monoxide affects the ability of the blood to use oxygen. The measure is the carbooxyhemoglobin saturation level (COHb) and is shown as percentage of blood cells affected. Based upon the table to the left such an exposure would have resulted in a COHb between 10 and 20 percent within the estimated exposure period. Twenty percent is considered a toxic exposure.[46]

The symptoms of carbon monoxide poisoning and the speed with which they appear depend on the concentration of carbon monoxide in the air and the rate and efficiency with which a person breathes. Heavy smokers can start off with up to nine percent of their hemoglobin already bound to carbon monoxide, which they regularly inhale in cigarette smoke. This makes them much more susceptible to environmental carbon monoxide. With exposure to 200 ppm for two to three hours, a person begins to experience headache, fatigue, nausea, and dizziness. These symptoms correspond to 15-25 percent COHb in the blood. COHb levels of over 20 percent in healthy individuals and over 15 percent in patients with a history of heart

[45] Peterson, J.E. & Stewart, R.D., 1975, "Predicting the Carbooxyhemoglobin Levels Resulting From Carbon Monoxide Exposures". J. Appl. Physiol., 39, 633-638. Abbreviations: Pco2 = mean partial pressure of O2 in lung capillaries, VA = alveolar ventilation rate, Vb = blood volume, M = equilibrium constant, DL = diffusing capacity of lungs, [COHb]0 = value prior to carbon monoxide exposure, Vco = rate of endogenous carbon monoxide production

[46] Noted on West Virginia medical examiner reports

or lung disease indicate the need for hospitalization[47]. During sedentary activities, immediate and severe symptoms of carbon monoxide toxicity occur at levels greater than 30 percent COHb; above this level a person could not take action for self-protection. Thirty percent COHb is equivalent to 0.5 L/min of oxygen. It is assumed that death occurs at 60 percent COHb as oxygen is reduced to 0.25 L/min. Between 30 percent and 60 percent COHb, a person would be alive but likely be unconscious.[48]

Mr. McCloy states that three of the SCSRs donned by the 2nd-left crew did not work. This would have resulted in those that had working units having to share their units, inhaling the toxic gases while others used their units. In addition, some of the crew participated in constructing a barricade[49] and attempting to signal the surface by hitting a roof bolt[50] with a sledge hammer. During these periods the individuals also removed their SCSRs for talking and other reasons, exposing themselves to toxic gases. As the SCSR reached the end of the production and miners were forced to inhale mine air they were also exposed to toxic levels of carbon monoxide.

All those that perished at Sago had COHb levels ranging from 64 percent to 78 percent. Since the rate at which carbon monoxide binds with hemoglobin is affected by individual factors, the lack of correlation between COHb levels of those whose SCSRs did not function and those that did does not reveal a relationship with SCSR use. The final stage of carbon monoxide poisoning is coma. Mr. McCloy speaks of others appearing to go "…to sleep or appeared to be asleep." He did not remember if everyone was asleep before he did because "really I didn't know because I really couldn't, per se --- the way it was --- looked like, there was like a corner, a place where they had mined --- stopped mining… a crosscut. But some

[47] Allred EN, Bleecker ER, Chaitman BR, Dahms TE, Gottlieb SO, Hackney JD, *et al*. "Acute Effects Of Carbon Monoxide Exposure On Individuals With Coronary Artery Disease". Health Effects Institute (HEI) Research Report No twenty-five. Cambridge (MA): HEI, 1989.

[48] A Thomas, E. Bernard and J Duker, "Modeling Carbon Monoxide Uptake During Work", United States Bureau of Mines, Pittsburgh, PA - Am. Ind. Hyg. Assoc. J(42) May, 1981

[49] "…it was already activated. Yeah. But I just took it out when I had to do that." McCloy page 50

[50] "…Probably set it down beside me where I was sitting, just leave it where I was sitting, and then get up, grab the hammer and hit the bolt, the same bolt and hit --- bang on the bolt." McCloy page 70

people were on down the ways, and they were a little bit difficult to see because of the distance. They were, yeah, within distance, but it's kind of hard to see."[51]

The physical evidence is that twelve SCSRs were found in the barricaded area. All had been deployed and examination of the chemicals inside the canisters indicated that they all had started producing oxygen. There is no way of knowing who used which SCSR as events unfolded since Mr. McCloy notes that those with SCSRs were sharing with those that did not have one. In addition, there was not a strict relationship between the location of the victims and the location of their assigned SCSR. In most cases the SCSR was found close to the victim to whom it was assigned however, in other cases they were found near other victims. Mr. McCloy's SCSR was found at the outby end of the barricade near the crosscut while he was at the extreme inby portion of the barricaded number three-entry directly adjacent to a pool of water. Several victims were found distant from their SCSRs as if they had abandoned them, in other cases they would have been within arm's length. It appears that at least one individual had tried to take an SCSR apart by breaking the outer protective cover.

There is no apparent relationship between the COHb levels reported by the medical examiner and reported operation of the SCSR. Of the three individuals whose SCSRs were reported nonfunctioning, one had the second highest COHb level, one the second lowest with the third only slightly higher. For those whose assigned SCSRs were found within arm's reach there is not a relationship between the visual or chemical analysis of the spent potassium superoxide and the reported COHb values.

Recovered 2nd-left SCSR examination revealed that one SCSR exhibited oxygen production far greater than all the other units. The COHb levels for the individual who was assigned that unit were not significantly lower than other victims as would be expected if his unit had performed better. There was also no other victim whose COHb was significantly lower indicating that he would have been using that unit, nor was Mr. McCloy found with an SCSR. The individual who was assigned this unit was found farthest inby on the right rib.

[51] From statement under oath by Randal L. McCloy June 19, 2006 starting page 84

Some of the victims wrote notes with the last entry dated at 4:25 p.m. It is unclear how many of the victims were conscious at that point. Because the atmospheric concentrations of carbon monoxide likely varied across the period and there was a difference in physiological tolerances, it is not possible to determine the point at which individuals would have reached the fatal COHb threshold[52].

When the rescue teams arrived on January 3, 2006 they did not find any standing water in 2nd-left. When evidence was surveyed starting on January 27, 2006 there was a pool of water approximately four feet from the point where the furthest inby victim was found. There was evidence that at least two miners had been lying in the area later found with standing water.[53] Many of the victims had cut pieces of ventilation curtain upon which to lie, and those who worked on the mine recovery reported that sitting on the floor would draw water into their clothing. Two of the recovered SCSRs examined between March 27 and March 31, 2006 at NIOSH's National Personal Protection Technology Laboratory were reported by federal examiners as having evidence of moisture within the canister and three others were reported as showing signs of mineralization. The three SCSRs with the greatest spent potassium superoxide percentages also were noted as having signs of moisture or mineralization in the sealed canisters.[54] One unit in this group was observed to have signs that dirt appeared to have leaked into the breathing bag. The only openings to the outside on the SR-100 are the relief valve and the breathing tube. It is uncertain what role ambient moisture prior to recovery or storage in sealed plastic bags while awaiting examination may have played in the observed results.

5.6-3h Randal McCloy's Experience

[52] The individual that wrote the 4:25 p.m. note had a COHb of 67 percent while other had values as high 78 percent. The partial pressure of CO required to achieve these levels at the point of death fall between 0.15 and 0.18 mm Hg. If respiration ceased at 4:30 pm (as estimated by the medical examiner) then the average CO over the 10 hours would have been between 700 ppm and 625 ppm as extrapolated from "The Rate of Carbon Monoxide Uptake by Normal Men" Am. J. Physiolol. 143, 594-608

[53] Conversation with Bill Tucker OMHS&T mine rescue team member who found Randal McCloy

[54] Conversation with NISOH/MSHA indicated they found what appeared to be material that had been dissolved in water then had dried – Randall Harris OMHS&T consultant

Mr. McCloy was interviewed on June 19, 2006 by MSHA. The OMHS&T was not given prior notice of the interview thus was not able to participate. Mr. McCloy, while able to respond to questions, was still recovering from the affects of carbon monoxide poisoning. Carbon monoxide causes neurological damage not only from the lack of oxygen while COHb is high but from the chemical reactions that occur as the body detoxifies itself[55]. As a result he had difficulty comprehending some of the questions he was asked and his responses were occasionally incomplete and differed from physical evidence. However, most of the information he provided does correlate with the physical evidence and is thus relevant. (There is no reason to believe that the facts presented by Mr. McCloy do not represent his recall of the events on 2nd-left.)

When he donned his SCSR Mr. McCloy remembers smoke he said, "Some, but not much. Not much at the time, but some"[56] Mr. McCloy commented on the breathing characteristics of the SCSR. Regarding temperature of the air he noted, "The heat in your lungs, because that's what you're breathing because of occolite (phonetic)[57], a chemical that's in it, which converts carbon dioxide into oxygen. It's a chemical reaction. " Regarding breathing resistance he noted "Well, you kind of had to work with it a little bit."[58]

Federal examination of Mr. McCloy's assigned SCSR indicated that it had only utilized 20-25 percent of its potassium superoxide. When the rescue teams entered the barricade Mr. McCloy was in a seated position with his back against the rib, his head slumped and was unconscious. His SCSR was located approximately 30 feet from where he was found. Additional SCSRs brought in by rescue teams were used to provide oxygen to Mr. McCloy until he was evacuated to a place where a positive pressure oxygen breathing mask could be placed on him.

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[55] Christian Tomaszewski MD, "Carbon Monoxide Poisoning" Vol 105 / No 1 / January 1999 / Postgraduate Medicine -- When carbon monoxide binds to cytochrome oxidase, it causes mitochondrial dysfunction that result in oxidative stress. The release of nitric oxide from platelets and endothelial cells, which forms the free radical peroxynitrite, can further inactivate mitochondrial enzymes and damage the vascular endothelium of the brain. The end result is lipid peroxidation of the brain, which starts during recovery from carbon monoxide poisoning. With reperfusion of the brain, leukocyte adhesion and the subsequent release of destructive enzymes and excitatory amino acids all amplify the initial oxidative injury. The net result is cognitive defects, particularly in memory and learning, and movement disorders that may not appear for days, weeks, or months following the initial poisoning..

[56] From statement under oath by Randal L. McCloy June 19, 2006 starting page 29

[57] The actual name is potassium superoxide but Mr. McCloy is correct in that the function of the chemical is to convert carbon dioxide and water vapor into oxygen.

[58] From statement under oath by Randal L. McCloy June 19, 2006 starting page 36

5.6-3i Regarding Jerry Groves SCSR

"I shared mine with my bolting buddy. What's his name? Jerry Groves.", Mr. McCloy said "I fought with it for I don't know how long, trying to mess with that valve, blow air through it or anything I could do, but nothing would work." When asked if Mr. Groves had tried to exhale into it in order to get the bags inflated, Mr. McCloy responded "Right. That's when I knew that he handed it over to me, because he couldn't get it started. And then I messed with the valve on it because I didn't know what else to do about it. Because I'm really --- I'm not too familiar with the inside --- inner workings of it because I don't build them." [59] When asked to describe how he shared his SCSR, Mr. McCloy stated, "I just sat up and handed it to him."[60]

Mr. Groves was found next to Mr. McCloy. His assigned SCSR was found approximately two feet from him. Federal examination determined it had produced 40-50 percent of maximum oxygen but also noted evidence of moisture in the canister.

5.6-3j Regarding Martin Toler Junior's SCSR

Mr. McCloy indicated that Mr. Toler had problems getting his SCSR to work. When asked if Mr. Toler had a functional self-rescuer on at that time he was making decisions and talking about where to go Mr. McCloy responded "He did not." [61]

While there was one SCSR for each individual in the barricade, neither Mr. Toler's nor Mr. Hamner's assigned SCSRs were recovered from the barricade, two unassigned SCSRs on records provided OMHS&T were recovered. Company records indicate that Mr. Toler was assigned SCSR serial number 106022 and Mr. Hamner was assigned SCSR serial number 101838. Two SCSRs were recovered that were not listed and whose serial numbers were 101868 and number 92652. One of these is likely the unit Mr. Toler carried into the mine that day and the other belonged to Mr. Hamner. Federal examinations indicated that unit

[59] From statement under oath by Randal L. McCloy June 19, 2006 starting on page 33
[60] From statement under oath by Randal L. McCloy June 19, 2006 starting on page 47
[61] From statement under oath by Randal L. McCloy June 19, 2006 starting on page 59

number 101868 had spent 25 percent potassium superoxide while unit 92652 had spent 40 percent but showed signs of moisture. The average for 2nd-left SCSRs spent potassium superoxide was 38.2 percent.

5.6-3k Regarding Thomas Anderson's SCSR

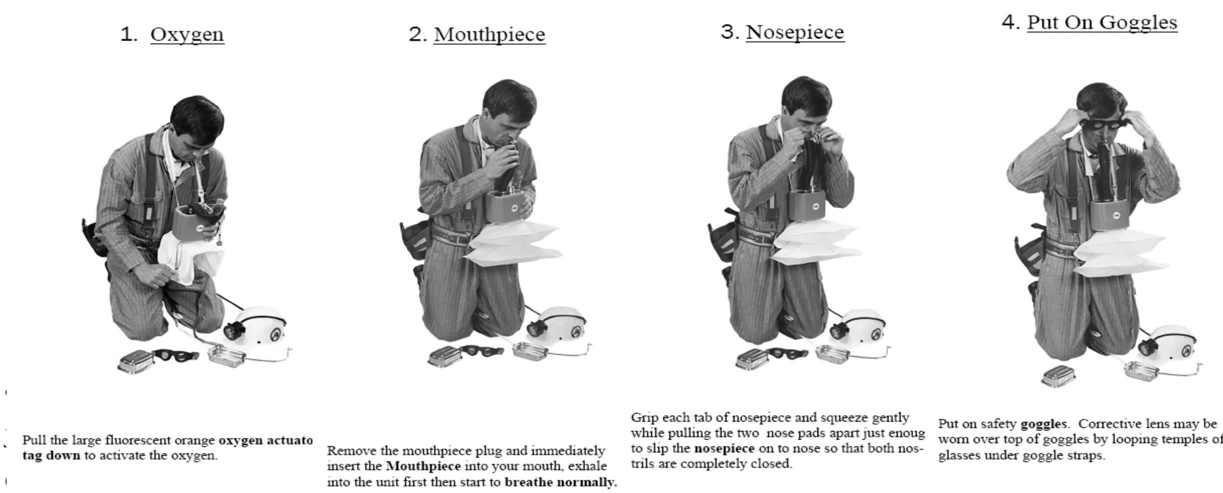
Mr. McCloy stated that Mr. Anderson's SCSR also did not work. He was unable to provide any indication regarding what was wrong with the unit.

Mr. Anderson and Mr. Toler made at least one effort and possibly more efforts to check the air in the section and listen for rescuers after the barricade was built. Mr. McCloy was asked if they took a self-rescuer when they left the barricade. He responded, "I don't know. I don't think." He thought they went out without a self-rescuer. Mr. McCloy also remembered that "…there'd be like two people and Toler or whoever would be the furthest away from the other nine, they would talk to each other, like yell to get words across, just like, did you see anything, just like that." The use of messengers spaced in a smoke-filled entry is a standard practice in mine rescue that the miners would know.

Mr. Anderson's assigned SCSR was found approximately 10 feet away. However within two feet were two other SCSRs belonging to other miners. It is unclear as to the significance of this. One of the two that were near him, had its protective outer case broken off as if someone tried to get inside the unit. Federal examination revealed that Mr. Anderson's assigned SCSR had produced 25 percent of its oxygen while the two units found near him, number 57604 had produced 10-15 percent and the previously mentioned unassigned number 92652 had produced 40 percent. SCSR 92652 is the unit previously mentioned with signs of dirt leaking into the breathing bag.

5.5-4 SCSR Training

State and Federal rules require at least annual training on SCSRs. The training conducted appears to have met these requirements and in some respects exceeded the SCSR specific training recommended by the manufacturer and NIOSH[62]. Gary Rowan said, “It's the only mine I've ever worked at that they actually had other classes you went to and stuff there on safety and stuff like this. We have them down at the office, everybody comes in.”[63] He went on to describe the process “… first they go up there, you know, one of them would sit in front of the --- in front of everybody, you know, and show them, go across everything and all the stuff there. And a lot of times they would have each person come up and don it and do everything except for put the mouthpiece in.”[64]



r steps in donning an SR-100 from a NIOSH SR-100 instructor’s manual.

The training conducted at Sago included review of the donning and inspection processes. The Sago miners also were required to individually demonstrate their ability to don the SCSR. The benefit of the training was a lack of confusion about getting the SCSRs on as Mr. Perry said, “It was more or less an automatic thing…”[65] This was reinforced by Mr. Hess who said,“…it's always been a big question in the back of my head, you know, if you have to put this thing on, do you think you could do it? And they tell you, you know, it takes approximately 30 seconds to get

[62] NIOSH SR-100 Instructors Guide
[63] From statement under oath by Gary Rowan February 15, 2006 starting on page 100
[64] From statement under oath by Gary Rowan February 15, 2006 starting on page 45
[65] From statement under oath by Arnett Perry January 26, 2006 starting on page 38

it on. That's about right. To get that thing broke down and get it on and get it working, it doesn't take very long." [66]

The conditions of recovered SCSRs provide hints that daily inspections were not conducted or at least were not done rigorously. This combined with no mention of the need to do daily inspections by any of those interviewed (see excerpt to right) indicate a likely lack of emphasis on this aspect of SR-100 use in training. This training information is conspicuous in the CSE document on Daily and 90 Day Inspections[67] distributed with their Acoustic Solid Movement Detector and takes up two of the six pages of the NIOSH SR-100 instructors guide distributed by MSHA.

PASS **Remain in Service**	**FAIL** **Remove from Service**
Date of Manufacture, less than 10 years	Date of Manufacture, if date exceeds 10 years.
Security band is secure.	Security band has been become slack, unattached, or unfastened.
Top and bottom moisture indicators are blue. Temperature indicator, located on the side of the unit should be pink or white.	If the top and bottom moisture indicators of either indicator is white or pink or damaged do not attempt to use. If the temperature indicator, located on the side of the unit is red, do not attempt to use.
Top and bottom covers are properly aligned.	Top and bottom covers are jarred or misaligned.
Top and bottom cover seals are properly aligned.	Top and bottom cover seals are cut, split or displaced.
No signs of significant trauma	Signs of significant trauma (beyond normal wear and tear) such as substantial dents in the top and bottom covers or substantial dents, breaks or punctures in the orange plastic outer cover. If the unit has been crushed, burnt, or suffered any damage that cause the security strap to become slack , unattached, or unfastened.

While the MSHA and NIOSH websites have documents that might have provided insights helpful to trainers, they were not commonly known nor were they commonly called out to instructors or miners. The common materials used by trainers did not focus on ways to maximize the duration of an SCSR once it is donned, what to if units did not perform as expected, or the physiological affects of carbon monoxide beyond that it is hazardous. In January 2006 there effectively was little information in the hands of instructors or miners regarding how SCSR's worked, what to do to maximize oxygen production or what to do if something did not work as expected.

[66] From statement under oath by Eric Hess February 14, 2006 starting on page 41
[67] CSE Corporation document SR-100 ASMD 10/02

Donned	Donned - Trouble	Not Donned	Miner	Crew Assignment	From Sworn Testimony			
					Deployed	Belt/Block	Removed	Belt/Block
1	0	0	Anderson, Denver (doc)	First-left	06:30+	46-block 4-belt	07:00	37-block 4-belt
0	1	0	Anderson, Thomas[1]	Second-left	Did not work	n/a	n/a	n/a
0	0	1	Avington, Paul	First-left	n/a	n/a	n/a	n/a
1	0	0	Bennett, Alva[2]	Second-left	06:30	12-block 7-belt	When outside	unknown
1	0	0	Bennett, James[3]	Second-left	06:30	12-block 7-belt	When outside	unknown
0	0	1	Boni, John Nelson	Outby	n/a	n/a	n/a	n/a
0	0	1	Boni, John Patrick	Outby	n/a	n/a	n/a	n/a
0	0	1	Carpenter, Gary	First-left	n/a	n/a	n/a	n/a
0	0	1	Grall, Ron	First left	n/a	n/a	n/a	n/a
0	1	0	Groves, Jerry[4]	Second-left	Did not work	n/a	n/a	n/a
1	0	0	Hamner, George[5]	Second-left	06:30	12-block 7-belt	When outside	unknown
0	0	1	Helms, Terry	Outby	n/a	n/a	n/a	n/a

[1] From statement under oath by Randal McCloy
[2] From statement under oath by Randal McCloy
[3] From statement under oath by Randal McCloy
[4] From statement under oath by Randal McCloy
[5] From statement under oath by Randal McCloy

Donned	Donned - Trouble	Not Donned	Miner	Crew Assignment	From Sworn Testimony			
					Deployed	Belt/Block	Removed	Belt/Block
0	0	1	Helmick, Randall	First-left	n/a	n/a	n/a	n/a
1	0	0	Hess, Eric	First-left	06:30+	46-block 4-belt	unknown	unknown
0	0	1	Hofer, Vernon Keith	Mine Maintenance	n/a	n/a	n/a	n/a
0	0	1	Jamison, James	Outby	n/a	n/a	n/a	n/a
1	0	0	Jones, Jesse[6]	Second-left	Did not work	12-block 7-belt	n/a	n/a
0	0	1	Jones, Owen	First-left	n/a	n/a	n/a	n/a
1	0	0	Keith, Hoy	First-left	Did not work	n/a	n/a	n/a
1	0	0	Lewis, David[7]	Second-left	06:30	12-block 7-belt	When outside	unknown
1	0	0	McCloy, Randal[8]	Second-left	06:30-06:45	12-block 7-belt	When outside	Unknown
1	0	0	Perry, Arnett Roger	First-left	06:40~	43-block 4 belt	07:00~	In mantrip at 37-block
0	0	1	Rowan, Gary	First-left	06:45~	43-block 4-belt	07:30	On surface
1	0	0	Ryan, Harley Joe	First-left	06:30+	46-block 4-belt	07:30	On surface
0	0	1	Schoonover, James Allen	Safety Director	n/a	n/a	n/a	n/a

[6] From statement under oath by Randal McCloy
[7] From statement under oath by Randal McCloy
[8] From statement under oath by Randal McCloy

Donned	Donned - Trouble	Not Donned	Miner	Crew Assignment	From Sworn Testimony			
					Deployed	Belt/Block	Removed	Belt/Block
0	0	1	Tenney, Christopher	First-left	n/a	n/a	n/a	n/a
0	0	1	Toler, Jeffrey Keith[9]	Superintendent	n/a	n/a	n/a	n/a
0	1	0	Toler Jr., Martin[10]	Second-left	Did not work	12-block 7-belt	n/a	n/a
1	0	0	Wamsley, Alton	First-left	06:30+	46-block 4-belt	07:45	One-belt
1	0	0	Ware, Fred[11]	Second-left	06:30	12-block 7-belt	When outside	unknown
1	0	0	Weaver, Jackie[12]	Second-left	06:30	12-block 7-belt	When outside	unknown
0	0	1	Wilfong, Denver	Maintenance Director	n/a	n/a	n/a	n/a
1	0	0	Winans, Marshall[13]	Second-left	06:30	12-block 7-belt	When outside	unknown
15	3	15						

33 people were underground at some point w/o apparatus
15 donned SCSRs and they worked
4 donned SCSRs and they did not work
14 chose not to don SCSRs
1 whose injuries did not allow donning

[9] From statement under oath by Randal McCloy
[10] From statement under oath by Randal McCloy
[11] From statement under oath by Randal McCloy
[12] From statement under oath by Randal McCloy
[13] From statement under oath by Randal McCloy

Photo 1

Example of debris from overcast at the mouth of second-left the crew would have encountered

Photo 2

Example of debris on the belt at the mouth of second-left

Photo 3

After the second-left crew abandoned their mantrip they crossed over into the intake and donned their SCSRs at 12-block leaving the covers on the floor in a circle – one unit's plastic outer casing was ripped off in an effort to remove a cover that apparently was stuck

Photo 4

Example of debris from stoppings near end of second-left track.

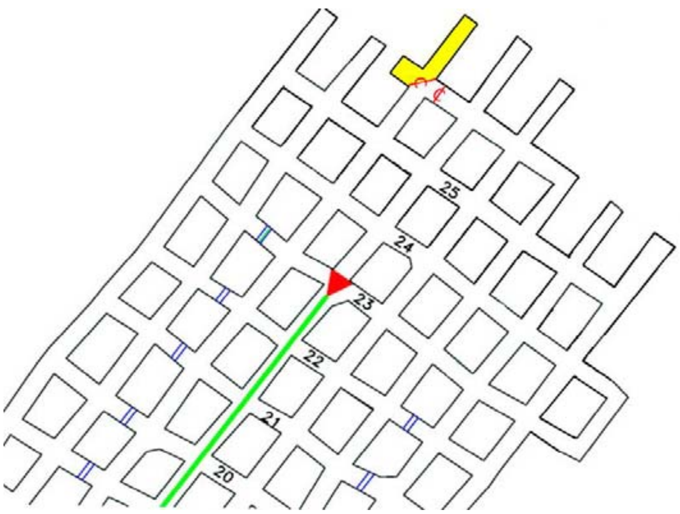


Figure 1

Location of second-left barricade in number three-entry at the face – shorter yellow area is the crosscut and the longer the number three entry

Photo 5

View into the barricaded crosscut looking from number four entry towards number three entry with the diagonal barricade curtain partly down

Photo 6

View into the number three entry barricade at looking toward the face

(The case of SCSRs in right foreground were brought by mine rescue teams for use in evacuation of survivors – some were used for evacuating Mr. McCloy)

Photo 7

Mr. McCloy's hat and several of the SCSRs used by the rescue team as they provided aid while bringing him out

These items were located on the left rib closest to the face of the number three-entry portion of the barricade

Photo 8

Second-left SCSR as found

Photo 9

Second-left SCSR as found

Photo 10

Second-left SCSR as found

Photo 11

Second-left SCSR as found

Photo 12

Second-left SCSR as found

Photo 13

Second-left SCSR as found

Photo 14

Second-left SCSR as found – white areas are where dust deposited by explosion has been disturbed revealing applied rock dust

Photo 15

Contents of Sago SCSR from unit with 10% spent potassium superoxide

Note large percentage of bright yellow potassium superoxide – bright white particles are lithium hydroxide – pale yellow and gray particles are reacted potassium superoxide

Photo 16

Contents of Sago SCSR from unit with 40-50% spent potassium superoxide

Note percentage of pale yellow potassium superoxide and moderate caking of chemical in canister mesh support

Photo 17

Contents of Sago SCSR from unit with 80-90% spent potassium superoxide

Note lack of yellow potassium superoxide and extensive caking of chemical in canister mesh support

6 RECOMMENDATIONS

Following this tragedy, many recommendations from all quarters were received. Some were directed to our state agency and legislature while others were directed to the federal agency and Congress.

Attached is a list of these recommendations and status. As the Investigative Team continues to study this incident and additional recommendations are presented, the report will be supplemented with those recommendations.

The Team will initially focus on the following two areas:

LIGHTNING

Although we have established that lightning was likely the cause of the explosion, our work is not complete until the specific mechanisms which allowed lightning to enter behind the seals at the Sago mine have been identified. We will attempt to build on the considerable base of knowledge acquired at Sago during the investigation. Monitoring at Sago this winter for lighting effects of winter electrical storms as proposed in Section 5.5-3 of this report will be done.

FORCES ON SEALS

To better-understand the forces that are possible in an explosion in order to design seals that can survive those forces. In this report we have presented the idea that the geometry of mine openings, specifically the effects of selective bottom-mining, may play a role in accelerating the velocity of pressure waves that are developed in an explosion, resulting in forces on seals that are beyond what was previously expected. Additional studies are needed to quantify these effects through experimentation and validated computer modeling.

Issues/Recommendations	Status
Increase number of Inspectors	Under Consideration
Omega Blocks	Studying Options
Hyperbolic chambers for CO poisoning	Studying Options
Operators shall revise all SCSR plans and submit those to the Director no later than 60 days after these amendments become final. (June 9, 2006)	WV 56-4 effective June 9, 2006
Operators shall place at least one cache at a readily available location within five hundred (500) feet of the nearest working face in each working section of the mine and each active construction or rehabilitation site. Distances greater than five hundred (500) feet not to exceed one thousand (1,000) feet, are permitted. However, where miners are provided with personal SCSR's rated for less than sixty (60) minutes, travel to these caches are not to exceed five (5) minutes as determined by the height/travel time chart as specified in Section 5.3.2.	WV 56-4 effective June 9, 2006
Each of these caches (nearest working face in each working section of the mine and each active construction or rehabilitation site) shall hold two (2) SCSR's that will provide at least 60 minutes of oxygen per unit for each miner. When each miner carries an SCSR that is rated for less than 60 minutes, in which case the cache shall hold three (3) SCSR's for each miner. The total number of SCSR's to be cached will be based on the total number of miners reasonably likely to be in that area.	WV 56-4 effective June 9, 2006
Operators shall ensure that caches described above also contain an escape kit containing a hammer, a tagline, a supply of chemical light sticks, and an escape-way map.	WV 56-4 effective June 9, 2006
Beginning at the storage cache located at the working section or active construction or rehabilitation site and beltlines, pumping and bleeder areas, and continuing to the surface or nearest escape facility leading to the surface, the operator shall station additional storage caches containing a number of additional SCSR's equal to or exceeding one each for the total number of persons reasonably likely to be in that area at calculated intervals that a miner may traverse in no more than thirty (30) minutes traveling at a normal pace, taking into consideration the height of the coal seam and utilizing the travel times as specified in Section 5.3.2.	WV 56-4 effective June 9, 2006
Thee Task Force recommends that SB-247 be modified by removing references to "certified intrinsically safe battery-powered strobe lights" due to the concern that damaged strobe lights would create a potential ignition hazard if damaged in an explosion. The Task Force recommends that each SCSR cache have a reflective sign with the words "SELF-RESCUER" or "SELF-RESCUERS" conspicuously posted at each such cache and that reflective direction signs shall be posted leading to each cache. Cache storage containers shall be of such construction as to protect the SCSR's from normal operational damage, be made of a material that is non-combustible, shall be easy to open during an emergency escape, and shall be noted on the escape-way map.	WV 56-4 effective June 9, 2006
Operators shall provide training in the proper use of SCSR's in simulated emergency situations, which may be on the surface, in all required SCSR training. Training should include but not limited to, manufacturer's required daily inspections, donning and starting the SCSR, ways to maximize duration of the unit, changing between SCSR's, communicating without removing the mouth piece, importance and use of goggles, how to know if the device has failed and what to do if it does, and limitations of the SCSR. Until such time as manufacturers offer an operable training SCSR operators are encouraged to save out-of-service units to activate during training as a supplement to currently available training models. All training shall be recorded and made	WV 56-4 effective June 9, 2006

Issues/Recommendations	Status
available upon request.	
Operators and contractors shall report to the Director all SCSR's in service by manufacturer, model, serial number, mine/contractor ID#, service dates, and results of required inspections. This information shall be submitted electronically as defined by the Director, updated quarterly and will include information on any units removed from service along with reasons. The Director shall compile and analyze the results of this information and distribute a report within 30 days by posting the report on the MHS&T web page, www.wvminesafety.org	WV 56-4 effective June 9, 2006
The Director shall require, in each underground mine, an emergency shelter/chamber, it shall be located in a crosscut no more than 1,000 feet from the nearest working face and shall be accurately located on mine maps.	WV 56-4 effective June 9, 2006
The Director may approve, as an alternative to a shelter/chamber, an additional surface opening located no more than 1,000 feet from the nearest working face and accurately located on mine maps.	WV 56-4 effective June 9, 2006
The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support needed to evaluate the performance of emergency shelter/chamber components/systems, and to review the effectiveness of emergency shelter/chamber plans.	WV 56-4 effective June 9, 2006
The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support needed to evaluate the performance of emergency shelter/chamber components/systems, and to review the effectiveness of emergency shelter/chamber plans.	WV 56-4 effective June 9, 2006
The applicant is to submit documentation including a certification by an independent licensed professional engineer that its unit meets the requirements.	WV 56-4 effective June 9, 2006
The Director shall maintain a current list of approved emergency shelter/chambers on the West Virginia MHS&T web site www.wvminesafety.org	WV 56-4 effective June 9, 2006
After an emergency shelter/chamber has been approved, any modifications must be submitted for approval by the Director.	WV 56-4 effective June 9, 2006
The Director shall convene the Mine Safety Technology Task Force not less than once per month through June 30, 2007 for the purpose of reviewing progress by manufacturers, regulators, and operators toward achieving the goals set forth in SB-247 and to review the functional and operational capability of necessary mine safety and health technologies. The Task Force shall submit a report to the Director of its findings and recommendations.	WV 56-4 effective June 9, 2006
No later than April 15, 2007 all underground mine operators shall submit an emergency shelter/chamber plan for approval by the Director. The design, development, submission, and implementation of the shelter/chamber plan shall be the responsibility of the operator of each mine.	WV 56-4 effective June 9, 2006
Within thirty (30) calendar days after submission of the emergency shelter/chamber plan, the Director shall either approve the emergency shelter/chamber plan or shall reject and return the plan to the operator for modification and resubmission, stating in detail the reason for such rejection. If the plan is rejected, the Director shall give the operator a reasonable length of time, not to exceed fifteen (15) calendar days, to modify and resubmit such plan.	WV 56-4 effective June 9, 2006

Issues/Recommendations	Status
Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its emergency shelter/chamber plan a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the emergency shelter/chamber and for installation and ongoing maintenance.	WV 56-4 effective June 9, 2006
After the Director has approved an operator's emergency shelter/chamber plan, the operator shall submit revisions to the emergency shelter/chamber plan at any time that changes in operational conditions result in a substantive modification. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the emergency shelter/chamber plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.	WV 56-4 effective June 9, 2006
If the Director, in his sole discretion, determines that an operator has failed to provide an emergency shelter/chamber plan, has provided an inadequate emergency shelter/chamber plan, has failed to comply with its approved emergency shelter/chamber plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.	WV 56-4 effective June 9, 2006
In developing the emergency shelter/chamber plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, advances in emergency shelter/chamber technologies and any other aspect of the particular mine the operator deems relevant to the development of the emergency shelter/chamber plan.	WV 56-4 effective June 9, 2006
A copy of the approved emergency shelter/chamber plan shall be provided to the mine rescue teams providing coverage for the mine. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above parties.	WV 56-4 effective June 9, 2006
The proposed emergency shelter/chamber plan shall: describe the structure and operations of the emergency shelter/chamber and its role in emergency response; ensure that emergency shelters/chambers are included in initial mine hazard training in such a manner that it is in compliance with all manufacturer's requirements and is provided yearly in addition to annual refresher training. All training shall be recorded and made available upon request; ensure weekly inspections of emergency shelters/chambers and contents shall be conducted by a certified mine foreman/fireboss and recorded in weekly ventilation examination book; ensure that weekly safety meetings review the current location of applicable emergency shelters/chambers and results of the latest inspection; ensure that emergency shelters/chambers shall be equipped with easily removable tamper-proof tags such that a visual indication of unauthorized access to the emergency shelter/chamber can be detected; and ensure that the mine's communication center shall monitor any communication systems associated with the emergency shelter/chamber at all times that the mine is occupied.	WV 56-4 effective June 9, 2006
The proposed emergency shelter/chamber shall include the ability to:	WV 56-4 effective

Issues/Recommendations	Status
provide a minimum of 48 hours life support (air, water, emergency medical supplies, and food) for the maximum number of miners reasonably expected on the working section; be capable of surviving an initial event with a peak overpressure of 15 psi and a flash temperature of 300 degrees Fahrenheit; be constructed such that it will be protected under normal handling and pre-event mine conditions; provide for rapidly establishing an internal shelter atmosphere of O_2 above 19.5%, CO_2 below 0.5%, CO below 50 ppm, and an 'apparent-temperature' of 95 degrees Fahrenheit; provide the ability to monitor carbon monoxide and oxygen inside and outside the shelter/chamber; provide a means for entry and exit that maintains the integrity of the internal atmosphere; provide a means for intrinsically safe power if required; provide a minimum eight quarts of water per miner; provide a minimum of 4000 calories of food per miner; provide a means for disposal of human waste to the outside of the shelter/chamber; provide a first aid or EMT kit in addition to a section first aid kit; have provisions for inspection of the shelter/chamber and contents; contain manufacturer recommended repair materials; provide a battery-powered internal strobe light visible from the outside indicating occupancy; provide a means of communications to the surface; and only contain MSHA approved materials where applicable.	June 9, 2006
The Director may require modifications to an emergency shelter/chamber approval or an emergency shelter/chamber plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.	WV 56-4 effective June 9, 2006
The Director shall require, in each underground mine, an integrated communication/ tracking system, a component of which shall be a communication center monitored at all times during which one or more miners are underground.	WV 56-4 effective June 9, 2006
The Director shall acquire, no later than July 1, 2006, the necessary technical/engineering support to evaluate the performance of individual communication/tracking systems and review the effectiveness of communication/tracking plans.	WV 56-4 effective June 9, 2006
The Director shall convene the Mine Safety Technology Task Force not less than once per month through June 30, 2007 for the purpose of reviewing progress by manufacturers, regulators, and operators toward achieving the goals set forth in SB-247 and other mine health and safety technology to promote the availability, functional and operational capability of necessary mine safety and health technologies. The Task Force shall submit a report to the Director of its finding and recommendations.	WV 56-4 effective June 9, 2006
No later than August 31, 2007 all underground mine operators shall submit a communication/tracking plan for approval by the	WV 56-4 effective

Issues/Recommendations	Status
Director. The design, development, submission, and implementation of the communication/tracking plan shall be the responsibility of the operator of each mine.	June 9, 2006
No later than August 31, 2007 all underground mine operators shall submit a communication/tracking plan for approval by the Director. The design, development, submission, and implementation of the communication/tracking plan shall be the responsibility of the operator of each mine.	WV 56-4 effective June 9, 2006
Within 15 days of approval by the Director, the underground mine operator shall submit as an addendum to its plan, a copy of any contract, or purchase order, or other proof of purchase of any equipment required to complete the communication/tracking system and for installation and ongoing maintenance.	WV 56-4 effective June 9, 2006
After the Director has approved an operator's communication/tracking plan, the operator shall submit revisions to the communications plan at any time that changes in operational conditions result in a substantive modification in the communication/tracking system. In addition, at any time after approval, the operator may submit proposed modifications or revisions to its plan along with reasons therefore to the Director. Within thirty (30) days after receipt by the Director of any proposed revisions or modifications to the communications/tracking plan, the Director shall either approve or reject the revisions, stating in detail the reasons for such rejection.	WV 56-4 effective June 9, 2006
If the Director, in his sole discretion, determines that an operator has failed to provide a communications/tracking plan, has provided an inadequate communications/tracking plan, has failed to comply with its approved communications/tracking plan, or has failed to provide a copy of any contract, purchase order or other proof of purchase required under this section, in an effort to delay, avoid or circumvent compliance with subdivision (2), subsection (f), section fifty-five, article two, chapter twenty-two-a of the Code or these rules, the Director shall issue a cessation order to the operator for the affected mine.	WV 56-4 effective June 9, 2006
In developing the communication/tracking plan and any revisions, the operator shall take into consideration the physical features of the particular mine, emergency plans, existing communication infrastructure, advances in communication/tracking technologies and any other aspect of the particular mine the operator deems relevant to the development of the communication/tracking plan.	WV 56-4 effective June 9, 2006
The proposed communication/tracking plan shall describe the structure and operations of the separate or integrated communication/tracking system(s) and its role in emergency response specific to the mine shall be detailed and submitted to the Director and, once approved, to the mine rescue teams providing coverage for the mine. Copies of the most recent version shall be available at the mine for emergency responders. As changes are made to the system, updated versions shall be submitted to the above.	WV 56-4 effective June 9, 2006
The proposed communication/tracking system shall include the ability for: a communication center monitored at all times during which one or more miners are underground. This center shall be staffed by persons holding a valid underground miners certificate, and trained and knowledgeable of the installed communications/ tracking systems, monitoring and warning devices, travel ways, and mine layout. Individuals not possessing a valid underground miner's certificate but working full-time as a communication center operator on or before May 25, 2006 shall be allowed to continue as communications center operators at that mine provided they will have successfully completed	WV 56-4 effective June 9, 2006

Issues/Recommendations	Status
no later than December 31, 2006 a certified 80 hour underground miners apprentice training program and documentation is available for inspection; knowing the location of all miners immediately prior to an event by tracking/locating in the escape-ways, normal work assignments, or notification of the communication center; knowing the location of miners in the escape-ways after an event providing the tracking system is still functional; check-in and check-out with the communication center by persons prior to entrance and exit from bleeders and remote or seldom used areas of the mine (all times shall be logged); allowing two way communications coverage in at least two separate air courses and at least one of which shall be an intake; maintaining communication/tracking after loss of outside power and maintain function both inby and outby of the event site with suitable supply of equipment for rapid reconnection; maintain a surface supply of communication/ tracking devices for use by emergency rescue personnel; allow for communication to surface at all required shelters/chambers; all miners and likely emergency responders shall be trained in the use, limitations and inter-operability of all components of the communication and tracking/locating system. This shall be incorporated into required training. All training shall be recorded and made available upon request;	
The operator shall provide a schedule of compliance for the communication/tracking plan, which shall include: a narrative description of how the operator will achieve compliance with above requirements; a schedule of measures, including an enforceable sequence of actions with milestones, leading to compliance; and a statement indicating when the implementation of the proposed plan will be complete.	WV 56-4 effective June 9, 2006
The operator shall provide as attachments to its communication/tracking plan: a statement of the analysis and evaluation required in developing its plan; a statement indicating the initial training dates for implementation of the communication/ tracking system and how the communication/tracking system will be incorporated in other required training; a statement regarding how the communications/tracking system will be tested and maintained; and the name of the person or persons representing the operator, including his or her title, mailing address, email address and telephone number, who can be contacted by the Director for all matters relating to the communication/tracking plan and weekly testing of the system.	WV 56-4 effective June 9, 2006
The Director may require modifications to a communication/tracking plan at any time following the investigation of a fatal accident or serious injury, as defined by Title 36, Series 19, Section 3.2, if such modifications are warranted by the findings of the investigation.	WV 56-4 effective June 9, 2006
Definitions of terms in Submitted legislative rule	WV 56-4 effective June 9, 2006
Research, development and adopt emergency measures to enhance protection against explosions from lightening entering underground mines and sealed areas; review and enhance equipment performance specifications for mine power stations	Studying

Issues/Recommendations	Status
Permanently ban the use of Omega Block as seals, because the current 20 psi standard is inadequate and because they may not even meet that standard	Effectively Done
Require mine operators to strengthen existing alternative seals by preparing, within 90d days, a plan to construct solid concrete block or comparable seal structures in front of (outby) Omega block seals, or take other appropriate precautions such as ventilating or inerting gases in the sealed abandoned areas, within reasonable deadlines clearly stated in the operator's plan for completing the task.	Studying Options
Evaluate the existing seal standards and consider, at a minimum, upgrading to the 50 psi standard adopted in other mining countries	MSHA Action
Require refuge chambers: Mine operators must develop a plan, by January 2, 2007, to purchase or construct refuge chambers, subject to state and federal approval of the design, number, and locations of such refuges, with the aim of having them installed by Jan 2, 2008	WV Approvals Pending for April 2007 implementation
Conduct a statewide review of all Self-Contained Self-Rescuers (SCSRs) currently in use to determine operability and detect damage, and require ongoing in-mine testing of SCSRs by miners volunteering to don and breathe through them to assess performance	State Inventory started – taken different approach to testing
Develop comprehensive emergency plans. Every West Virginia mine must have a comprehensive mine emergency plan integrated with federal, state and operator roles and tested periodically by the state for effectiveness	Plans were required still need regular review an practice
Ensure that miners have two-way communications: Aggressively accelerate the testing, approval and adoption of robust, redundant, wireless two-way communication systems in all underground mines	Working on solutions for August 2007 implementation
Require implementation of tracking systems via the 'default option' of installing currently available one-way electronic personal emergency and tracking devices	Working on solutions for August 2007 implementation
Undertake a comprehensive review of West Virginia mine rescue systems, including regulations, training, equipment and coordination with West Virginia's Office of Homeland Security and Emergency Management	Underway
Require installation of lifelines in all primary escape ways in underground mines, equipped with directional cones to guide miners to safety	Done
Improve OMHS&T emergency response capabilities.	Some actions taken not all
Better plan and communicate mine rescue and other event participation needs to Inspectors at Large that disrupt the inspection process to allow better planning to ensure completion of mandated inspections.	Action Needed
Have the state office of technology perform a communications and computing technology assessment including the Mine Inspection Support Environment description with recommendations for improvement and cost estimates for implementation.	Done
Hire five additional safety instructors and provide vehicles necessary to visit mine sites with a focus on accident prevention	In Budget

Issues/Recommendations	Status
through education and training	
Mine Rescue Team Rule	In Force
Electricians Rule	In Force
Mine & Industrial Accident Rapid Response System	Under way

7 LIST of APPENDICES

APPENDIX 3

The Rescue

- **Chronology Notes**
- **International Coal Group—Request Submitted During Rescue**
- **Drilling Activities**
- **Copy of Air Analysis**
- **Mine Rescue Teams**

APPENDIX 4

Mine Recovery

- **Mine Recovery—Maps 1-5, Covers Entire Mine, Map 4 and 5 covers the Explosion Area**
- **Listing of Approved Recovery Plan Submissions**
- **Approved Mine Recovery Plans**
- **Listing of Recovery Participants**
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APPENDIX 5

The Investigation

5.1 Statistics and Fact-finding

- **Inspections and Violations**
- **Victim and Accident Information**
- **Listing of Interviewers**
- **Listing of Individuals Interviewed**

5.2 Evidence Documentation

- **Index Map**
- **Folio Map 1 through 12 (of 29)**
- **Folio Map 13a through 29 (of 29)**

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- **Summary of Approved Construction**
- **West Virginia Code—Unused and Abandoned Parts of Mine**
- **Approvals and Requests for Sealing**
- **Seal Inspection**
- **Seal Foundation Test Boring**

5.4-1 Mapping of Explosion Forces

- **Flames and Forces Map**
- **Belt Hanger Survey 1- Map**
- **Belt Hangers- Maps 1 through 7 (of 7)**

- **Floor Contour Map**
- **Roof Contour Map**

5.4-2 Origin of Explosion

- **Evaluation of Roof Anomaly -- Letter**
- **Description of Pump Cable Lengths and Associations**

5.4-4 Methane Concentrations

- **Methane Liberation Study**
- **Mass Balance Calculations**
- **Pre-Explosion Airflow**

5.4-5 Coking Tests- MSHA

- **Coking and Rock Dust Survey (Map and Data)**

5.5-2 Lightning: Linkage to Explosion

- **STRIKEnet Report LA 105034**
- **Forensic Survey of Poplar Tree**
- **Time Differential in CO Monitor's Computer at Sago Mine**
- **Pyott Boone Data**
- **Results from Analysis of Seismic Data for the January 2, 2006 event near Sago, WV**
- **Map of Resident Interviews**
- **Lightning Detection Networks – Krider (Attachments A, B, C, D, E and F)**

5.5-3 How Lightning May Have Entered the Mine

- **Electrical System—Map Showing Conductors and Resistivity Test Locations**
- **Description of Pump Cable Lengths and Associations**

- **Description of Gas Lines and Wells**
    - **Summary of possible paths**
    - **Map of gas lines and wells**
- **Water samples : Old 2nd Left Section**
- **Map of Telephone Lines**
- **Geophysical Log Core Hole SF 52-06**