1-20-07

Adobe Acrobat 5.0 or higher is required to view these files.

The *Errata* entries below are corrections and clarifications made to the Sago Report since its initial release on December 11, 2006. These changes have been incorporated into the Sago Report document posted on the OMHS&T website.

Page and line references are with respect to the initial release document. Minor changes, such as font style, punctuation, illustrations' format, text spacing, etc., may not be listed.

Any revisions made *after 1-20-07* will appear in the *Errata* page on the website document.

ERRATA

12-11-06 to 1-20-07

Bold: text which has been added

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

Definitions:

NIOSH: **National Institute for Occupational Safety and Health**

Section 2.1

p. 2, line 14: Coal is produced using remote controlled extended cut continuous mining ~~achines~~ **machines**, with shuttle car type face haulage.

Section 3

Pages and footnotes renumbered.

Section 3.3

p. 22, par. 3: Based on apparent high concentrations of carbon monoxide, and evidence found with the ~~secon-left~~ **second-left** crew as well as reports from the medical examiner, it appears that only Randal McCloy survived until January 3.

p. 23, par. 3: Mr. McCloy reported that there were too few self-rescuers to go around, since ~~three~~ **four** miners had been unable to make theirs work.[79] Those ~~that~~ **who** had working units shared with those next to them. Mr. McCloy ~~reports~~ **reported** trying to assist Jerry L. Groves **with** ~~get~~ **getting** his **SCSR** started "…we tried to get **it** working, and it didn't work" "…it aggravated me the most because really I wanted his to work."

<u>Section 5.2-1</u>

p. 1, par. 2: The effort was largely conceived and organized by personnel within MSHA Tech. **Support.**

<u>Section 5.2-2</u>

The WVOMHS&T, as part of the investigation, requested and obtained a dewatering pump with its power cable and other components that ~~was~~ **were** found in the previously sealed area.

<u>Section 5.3-1</u>

p. 2, par. 1: *See transcripts of persons interviewed* **at: www.wvmine.safety.org.**

p. 2, par. 3: *See transcripts of persons interviewed at:* ~~*www.wv.safety.org*~~ **www.wvmine.safety.org.**

<u>Section 5.3-2</u>

p. 1, line 2: Constructed of Omega ~~348~~ **384** Blocks and a high-strength (~~600~~ **2000** PSI) ~~Block~~ Bloc Bond mortar, these seals are considered an alternative to the standard Mitchell/Barrett seal[1].

p. 4, line 1: Prior to installation of the ~~#5, #6, and #7~~ **#6, #7, and #8** seals, an 8-guage, 4" wire roof mesh was installed against the roof as supplemental roof protection.

p. 4, line 6: No **confirmed** components of the water trap were discovered during the investigation.

p. 5, line 14: (4) the average width of seal #1 was 21.2 feet ~~and did not have a pilaster design~~, and

p. 5, line 15: (5) the average width of seal #3 was 20.36 feet ~~and did not have a pilaster design~~.

p. 6, line 9: Installing the middle board was often a most difficult ~~taske~~ **task**.

<u>Section 5.4-1</u>

p. 1, line 5: By this time vertical boreholes had been drilled near **the** lowest elevation of the mine at the back end of Old 2nd Left in order to re-establish ventilation**,** and regulators had been installed to control access and airflow.

p. 1, line 8: 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.

p. 8, par. 2 (heading): <u>~~Severely~~ **Severe,** omni-directional deformation of roof pans</u>

p. 13, photo 8 (caption): Occasionally, belt hangers were suspended from roof bolts when the height of **the** mine roof was ~~excess~~ **excessive** ~~on advance~~.

p. 15, footnote(11): Areas that were not second-mined sustained higher velocities, based on ~~comparing~~ **a comparison of** relative amounts of damage.

Section 5.4-2

p. 2, footnote (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.

p. 3, line 15: They are reference in ~~Map 1~~ **Map 1A** as “Anomaly1” and “Anomaly 2”.

p. 4, Map 1 (caption): ~~Map 1~~ **Map 1A**.

Section 5.4-3

p. 2, line 3: A variety of factors such as the local site conditions and mine geometry can affect the forces ~~that are~~ that are produced in a mine explosion.

p. 2, footnote (3): “Omega ~~348~~ **384** Block as a Seal Construction Material”, C.R. Stephen; 1990~~,~~ **.** “Designs for Rapid In-situ Sealing,” M. ~~Sapco~~ **Sapko**, E. Weiss, J. Trackemas, C. Stephan; 2003.

p. 3, Figure 2 (caption): Generalized layout of facility used to test Omega **block** ~~Seals~~ seals.

p. 3, Figure 3 (caption): This is a schematic of the “open chamber” test of Omega **block** ~~Seals,~~ seals.

p. 5, footnote (7): **“Pressure-piling” is a local dynamic effect which can cause high local explosion pressures; *GexCon- Gas Explosion Handbook.***

p. 6, footnote (10): A ~~venture~~ **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.

p. 9, line 2: 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 and~~ 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].

Section 5.4-4

p. 2, footnote (2): Approximately ~~15~~ **13** hours of no data collection occurred during the sample period.

p. 3, line 5: ~~This~~ **These** data are given in **Appendix 5.4-4:** *MSHA Methane liberation studies #1 and #2).*

p. 3, line 6; 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 ~~created by~~ **ventilated from the mine following** the explosion.

p. 3, line 15: For purposes of this calculation the fuel for the explosion is considered to have been entirely methane gas, although some minor amounts of other ~~gases~~ **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].**

p. 3, footnote(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.

p. 3, footnote(5): CO_2 concentrations of ~~380~~ **were reduced by 375** ppm ~~was subtracted from data values for this combustion~~ **to adjust for ambient concentrations**.

p. 4, line 2: 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 ~~eight (8)~~ **seven (7)** flow readings[6] out this entry and converted to total weight using densities at 1.013 bar and 59-degrees F.

p. 4, Figure 1 (caption): Volumes have been adjusted for the ~~380~~ **375** ppm ambient air concentration.

p. 4, footnote (6): Taken between 1-2-06 8:40 AM EST and 1-2-06 9:37 ~~AM~~ **PM** EST.

p. 5, par. 3: Concentration allocations are based on **approximately** nine (9) ~~simultaneous~~ **sets of** hand-held gas detector readings **taken at approximately the same time** from each of the #1, #2, #3, and #4 entries.

p. 6, par. 1; This chart ~~(Figure 1)~~ **(Figure 3)** shows a linear rate of decline for methane liberation over the three (3)-month time period.

p. 6, Figure 3 (caption): This graph shows the history of average daily methane ~~concentrations~~ **emissions** over time **within the sealed area of Old 2nd Left,** as determined by an analysis of gas data recorded at Sago Mine.

<u>Section 5.4-5</u>

p. 1, footnote (1); [1] From MSHA document CAI-2001-20-32, Fatal Underground Coal Mine Explosion at No. 5 Jim ~~Walker~~ **Walter** Resources September 23, 2001

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

<u>Section 5.5-1</u>

p. 4, footnote (3): **Except for damage to the 12 kV power line as noted and described in Section 5.5-3d.**

p. 4, Map 2 (caption): **Two (2) of the** ~~Lighting~~ **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.

<u>Section 5.5-2</u>

p. 1, par. 2: Several commercial lightning detection networks provide lightning data for almost any location in the country and requests for reports ~~for~~ **of** these ~~reports~~ **events** can be made online.

p. 1, line 3 (of un-captioned table): ~~01/02-06~~ **01/02/06** ~~06:38:35.838~~ **06:38:51.838** EST 38.975 -80.123 -12.6

p. 2, par. 1: The force of the lightning ~~gouged~~ **produced** a small **gouge** ~~into~~ **in** the ground at the base of the tree.

p. 4, line 10: 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.

p. 7, line 1: A copy of this report is given in **Appendix 5.5-2**: ~~*Report of Martin Chapman, VPI&SU*~~ ***Results from Analysis of Seismic Data for the January 2, 2006 event near Sago, WV.***

p. 7: Time of ~~+101~~ **+38.8** kA lighting strike 6:26 AM 35.552 sec/ +/- .0005 sec.

p. 7: Time of ~~+38.8~~ **+101** kA lighting strike 6:26 AM 35.680 sec/ +/- .0005 sec.

p. 18, (first section header): 5.5-2f Examination of Data from Lightning Detection Networks~~, by E. Philip Krider, PhD.~~

p. 21, line 1: 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~~ **5.5-2**: Attachment B).

p. 21, line 4: 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)**.

p. 21, line 8: An evaluation of the overall NLDN detection efficiency and other performance parameters on January 2, 2006, is given in Appendix ~~5.~~5 **5.5-2**: Attachment D.

p. 21, line 10: 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~~ **5.5-2**: Attachment E.

p. 22, line 10: 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.

p. 26, line 4: The results are summarized in Appendix ~~5.5~~ **5.5-2**: Attachment F.

p. 26, line 5: The key point in Attachment F is that there is no evidence of any small ground strokes or cloud discharges in the region ~~of the~~ **in a** 10 second interval prior to the first positive stroke that was reported by the NLDN.

p. 26, par. 2: Information from multiple time-synchronized sensors indicates that there were two (2) large cloud-to-ground lightning strikes near Sago Mine at ~~that~~ **the** same time that the mine explosion occurred.

p. 26, par. 4: The network is designed to ~~see~~ **detect** and ~~record~~ **report** cloud-to-ground discharges. However, ~~strikes~~ **strokes that have** less than 3 kA peak ~~currents~~ **current**, ~~strikes which are cloud-to-cloud~~ cloud discharges, or ~~strikes of~~ upward lightning are not normally ~~detected with~~ **reported** by the present lightning detection systems.

Section 5.5-3

p.1, par. 1: There are many possible pathways or mechanisms whereby the electromagnetic energy from lightning could have entered the Sago Mine, and which ~~mechanism~~ **mechanisms** ~~was~~ **were** actually involved ~~is~~ **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 ~~lighting~~ **lightning** energy could have entered the mine.

p.1, par. 2: 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.

p. 1, line 14: 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, ~~tracks,~~ **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) a) 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.**

p. 2, line 1:

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.

p. 2, line 7: As of this writing**,** there is no clear proof of the precise mechanism by which the electricity from lightning entered the **Sago** mine.

p. 4, line 8: 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 ~~an~~ **one or more** upward ~~discharge~~ **discharges** from tall**, nearby** structures. t~~hat was close to the mine~~, ~~but was not detected by the NLDN.~~

p. 4, line 19: A key question ~~of~~ **in** this investigation is "How did the electromagnetic energy from lightning couple into the Sago mine?"

p. 6, line 13: These accounts could be due to an upward or triggered lightning discharge that was initiated by ~~the~~ **a nearby** tower.

p. 12, line 10: 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 12 kV powerline leading to the mine was found, as previously noted.**

p. 13, line 3: 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 area~~ the region ~~were~~ **where the** explosion is believed to have originated.

p. 20, line 5: A larger and more detailed map is included in Appendix ~~5.5~~ **5.5-3**: **Map of Gas Line and Wells.**

p. 21, line 9: In the case of Sago Mine, **there are** several ~~occur~~ wells near the mine, but none pass through the mine void.

p. 21, line 16: Descriptions of these two lines are contained in Appendix 5.5-3: Description of ~~Gaslines~~ **Gas Lines and Wells**.

p. 22, Map 4 (caption): ~~Map 4~~ **Map 3A**.

p. 23, line 6: Work is still on-going to determine whether the network of gas wells and gas lines may have played a role **in** coupling ~~the lightning current~~ **high voltages** into the sealed area, and particularly with respect to any upward lightning that may have been initiated by tall ~~structures~~ **towers** several miles away.

p. 32, Map 7 (caption): ~~Map showing layout~~ **Layout** of Verizon telephone ~~line~~ **lines**. **A larger version of this map is contained in Appendix 5.5-3: *Map of Telephone Lines*.**

p. 34, line 12: In 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 ~~loot~~ **loop** that, under the right conditions, could have produced sparks across small gaps and discontinuities in the mesh that ignited the methane.

p. 34, line 17: 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[1] at that time.

p. 34, line 22: The horizontal pump cable ~~undoubtedly~~ **may have** brought the ground potential (voltage) of the nearby well casing ~~(see Map 8),~~ the pump, ~~and/or~~ **and** water **(see Map 8)** into close proximity to a different ground potential (i.e. that of ~~the roof mesh or a different "ground") in the mine.~~ **the walls, floor, or roof mesh) in the mine void, and if these differences were large enough, they could have produced corona discharges.** ~~Any large DIFFERENCESs in these potentials could have produced corona discharges[20]~~

p. 35, footnote (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 ~~lacking a water proof gasket this switch box was full of mine wate~~r **was suspended from the wire roof mesh by its retainer chain.**

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[1] 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 suspended from the wire roof mesh with a chain and cable hook.

p. 35, footnote (20): ~~Krider, 2006. A feature associated with corona discharge which occurs when one of two electrodes in a gas has a shape causing the electric field at its surface to be significantly greater than that between the electrodes.~~

p. 37, line 3: ~~The layer~~ **Layers** of shale and sandy shale are between the sandstone layers, ~~that~~ and have ~~relatively~~ **a comparatively** low resistivity. The layer of shale between the coal and the Rider seam **appears to generally have** ~~has~~ the lowest resistivity of all.

p. 37-39, (footnotes 21, 22, and 23 renumbered to 20, 21, and 22, respectively).

p. 38, par. 2: The wire roof mesh ~~runs~~ 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 mine floor.

p. 38, line 18: This is the first step in developing protective measures to guard aganst similarly destructive lightning accidents in the ~~futures~~ **future**.

Section 5.6

p. 12, line 8: Of these, fifteen donned SCSRs[21] that operated adequately, fourteen ~~choose~~ **chose** not to don their SCSRs[22], ~~three~~ **four** SCSRs were reported as not functioning properly[23], and one suffered injuries such athat he could not have donned his SCSR.

p. 14, line 10: ~~Three~~ **four** on the 2nd-left crew were reported as not working properly.

p. 30, line 4 (below table): ~~3~~ **4** donned SCSRs and they did not work.

p. 33, Photo 7 (caption): Mr. McCloy's hat and several of the SCSRs used by the rescue team as they provided aid while ~~brining~~ **bringing** him out.

Section 6

p. 1, line 8: 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.