APPENDIX S

SEDIMENT ANALYSIS FROM WATER BASKETS AND SPRAY NOZZLES

Appendix S
Sediment Collection and Analysis from Water Baskets and Spray Nozzles

Water Baskets

Background
On March 10, 2011 sediment was collected from two wire mesh filters obtained by MSHA's Accident Investigation Team from UBB. The filters are designated as PE-0448 (1 South Belt Water Basket) and PE-0423 (1 North Panel Pump Car).

After sediment was collected from the filters, the sediment was weighed and then subjected to separation of particle sizes by a series of sieves. The sieves were stacked in order of decreasing grain size from top to bottom, with U.S. Standard Sieve Size No. 8 on top, followed successively downward by No.'s 60, 100, 140, 200, and 325. A pan placed at the bottom of the sequence collected any particles small enough to pass through the No. 325 sieve. The No. 8 sieve uses a mesh spacing of 2.36 mm, which corresponds to the geological size designation of "granule" and was used to catch visibly large particles such as cellophane wrappers and plant debris. The No. 60 sieve uses a mesh spacing of 0.250 mm, which corresponds to the boundary between the geological designations for medium-grained sand and fine-grained sand. The No. 100 sieve uses a mesh spacing of 0.150 mm, which corresponds to the geological particle size of fine sand. The No. 140 and 200 sieves use a mesh size of 0.106 mm and 0.075 mm, respectively, which correspond to the upper and lower ranges of the geological particle size of very fine sand. The No. 325 sieve uses a mesh size of 0.045 mm, which corresponds to the geological particle size of coarse silt. Any particles collected in the bottom pan would be designated as -325 mesh, and would represent material finer than coarse silt.

After the stack of sieves was placed on a shaker table for 10 minutes, each size fraction was weighed, and the particles in each fraction were described by spreading the particles on a clean, white sheet of paper and inspecting the particles with a 10-power lens under bright light. Upon completion of the description, each size fraction was stored separately in a glass vial marked with the PE number and size fraction. Upon completion of all documentation activities, the vials were placed together in a freezer bag, which was stored inside the respective water basket.

Observations
PE-0448
Sediment was collected from the 1 South Belt water basket by dumping loose material out onto a clean, white sheet of paper. Additional material was obtained by brushing the inside of the basket with a paint brush and depositing any resulting material on the sheet of paper. The screen mesh of the basket itself was generally dirty and appeared mostly clogged with fine, gray material. A dial-gauge micrometer indicates that the mesh screen size is 0.01 inches, which is equivalent to 0.254 mm. Therefore, material corresponding to U.S. Standard Sieve Size No. 60 (0.250 mm) and smaller would theoretically be able to pass through the water filter. This size would represent the

upper boundary of the "fine sand" geological particle size. After all available sediment was collected on the white sheet of paper, it was funneled into a glass dish for weighing on a digital balance. It was determined that 1.15 g of sediment was collected from the water basket. It should be noted that due to likely measuring error, the aggregate weight of size fractions represents 110% of the initial sample weight.

- The +8 sieve material weighed 0.12 g and consisted of fibrous mats of interlocking grass blades and stems. The agglomerated grass blades hosted sporadically distributed, 1 mm-diameter particles of coal, biotite, quartz, and yellowed cellophane wrappers, along with rare, spherical slag pellets.
- The +60 sieve material weighed 0.8 g and consisted of angular fragments of coal (30%), angular grains of frosted quartz (20%), thin sheets of limonite and goethite-altered rust flakes that were attracted by a small magnet (10%), yellowed cellophane (<1%), and plant debris that consisted dominantly of seed pods (40%). There were also a few grains of broken concrete in which the aggregate sand was visible, one of which hosted heavy iron staining that suggested rusted rebar.
- The +100 sieve material weighed 0.17 g and consisted of angular coal fragments, a large number of spherical seeds, and abundant plant debris that dominated the sample. Also present were angular rust flakes and only minor quartz.
- The +140 sieve material weighed 0.04 g and consisted of angular coal fragments, quartz, plant debris, limonite-altered rust fragments that were attracted by a small magnet, and feldspars. The plant debris is represented by long fragments of cellulose stalks longer than +140 but of sufficient diameter to pass through the mesh.
- The +200 sieve material weighed 0.04 g and consisted of coal, quartz, feldspars, and minor limonite-altered rust. Plant debris included only a few fibers of cellulose.
- The +325 sieve material weighed 0.04 g and was dominated by coal and quartz, with grains that are subangular to subrounded due to abrasion. Minor limonite-altered rust flakes were present, and minor plant debris consisted of individual hair-like fibers.
- The -325 sieve material weighed 0.02 g and consisted almost exclusively of coal (40%) and quartz (60%).

<u>PE-0423</u>
Sediment had previously been collected from the 1 North Panel Pump Car on February 18, 2011 and stored in a plastic container, with preliminary descriptions of the material presented in a March 8th memorandum from Matthew Babington, Esq. (SOL) to Benjamin Wood, Patton Boggs, LLP. The collected material was viewed by all parties attending the testing in order to confirm that the container and material was the same as portrayed in photos included with the March 8th memorandum. The sample was weighed and represented 8.32 g of material.

- The +8 sieve material weighed 0.58 g and consisted of cellophane and tinfoil-coated wrapping paper of the type used for snacks. Printing on the clear cellophane indicated that it represented a package of "Cheddar and Bacon" crackers and printing on the foil-coated paper indicated that it had represented a bag of “Potato Skins” chips. Other clear wrappers were unmarked, but hosted a UPC code. The remaining material included 5 mm-diameter leaf fragments and a single shale pebble that was 8 mm in diameter.

- The +60 sieve material weighed 7.57 g and consisted dominantly of plant debris (65%) and coal fragments (30%). Plant debris consists of dried leaf fragments, grass stems and/or pine needles, small twigs, fragments of wood chips, and grass blades. Small red plastic fragments were intermixed with this material. The mineral fraction was dominated by square and angular coal fragments, with minor quartz grains. A small magnet was used to attract several small rust flakes, which showed orange-colored limonite alteration.
- The +100 sieve material weighed 0.11 g, and consisted of angular coal fragments (40%), angular limonite-altered rust fragments (40%), plant debris (10%), and quartz grains (10%). The plant debris represents grass blades and twigs, with small, hair-like stems and numerous spherical seeds.
- The +140 sieve material weighed 0.03 g and consisted of subangular to subrounded quartz (40%) and angular coal fragments (40%), with limonite-stained rust fragments (10%), and minor plant debris (10%). Plant debris consists of hair-like fibers.
- The +200 sieve material weighed 0.03 g and consisted of quartz (55%), coal (35%), plant fibers (7%), and limonite-stained rust fragments (3%). This sample is noticeable lighter in color compared to other samples, due to its greater quartz content.
- The +325 sieve material weighed 0.04 g and consisted of quartz (60%), coal (25%), plant fibers (10%), and limonite-stained rust flakes (5%). Quartz grains are subangular to subrounded, compared to coarser samples in which quartz was angular, reflecting abrasion of grains.
- The -325 sieve material weighed 0.02 g and consisted of quartz (80%), coal (15%), and plant fibers (5%) with no other material present.

Conclusion

It appears that with decreasing grain size, noted especially with the +140 (0.106 mm) material that corresponds to the geological particle size of very fine sand, the samples begin to be dominated by quartz grains of the very fine sand to coarse silt size. The increase in the degree of rounding corresponding to decreasing grain size is an indication that quartz is more able to survive the processes of mechanical abrasion at smaller sizes. Quartz and coal are the only naturally occurring minerals in the sediment, which at larger size fractions host significant plant debris and man-made material such as rust flakes and snack wrappers.

Based on a measurement of the screen size of the water baskets, which indicates a mesh spacing of 0.254 mm (0.01 in.), material smaller than the No. 60 mesh size could have been able to pass through the filter baskets. The -60 to +140 material is generally dominated by plant debris and coal, while material smaller than +140 is dominated by very fine-grained quartz sand, and by coarse-grained quartz silt. These size fractions represent less than 1.5% of the total weight of collected material, which is generally dominated by plant debris and coal.

Based on the analysis of the filter basket sediment, it should be expected that any downstream equipment might contain -60 (less than 0.250 mm) material that could include plant debris, coal, quartz, and rust flakes. It would be unlikely that material larger than 60 mesh (0.250 mm) found in any downstream equipment would have passed through the filter baskets, and would instead have to have been derived from an intervening source. It should also be noted that no shale, and only very sparse mica flakes, were documented in the water basket sediment. Therefore, clay minerals identified in downstream equipment would be expected to have a source other than the water supply, such as shale pulverized during the mining process.

Spray Nozzles

Background

On March 17-18, 2011 sediment that had been previously collected from spray nozzles obtained by MSHA's Accident Investigation Team from UBB was described in terms of grain size and mineralogy. Fine-grained material was sent to an independent, commercial laboratory for identification by x-ray diffraction. Under a previous protocol (Protocol for Collecting Material and Measuring Dimensions of Spray Nozzles Recovered from Longwall Shearer, Performance Coal Co., Upper Big Branch Mine), sediment had been collected from 20 spray nozzles and stored in glass vials. In some cases, sediment was collected from different portions of the same nozzle. The vials of sediment were documented under the same nomenclature as the spray nozzle from which they were collected, including PE-0391, PE-0395, and PE-0397.

Sediment from each vial was separated into three size fractions by passing it through two screens. The top screen was U.S. Standard Sieve Size No. 12, which corresponds to 1/16th-inch; the second screen was U.S. Standard Sieve Size No. 60, which corresponds to the 0.01 inch screen size used in the longwall shearer water supply basket filters.

After the stack of sieves was placed on a shaker table for 10 minutes, each size fraction was weighed, and the particles in each fraction were described by spreading the particles on a clean, white sheet of paper and inspecting the particles with a 10-power lens under bright light. Upon completion of the description, each size fraction was stored separately in a glass vial marked with the PE number and size fraction. Upon completion of all documentation activities, the vials were placed together in a freezer bag, which was stored inside the respective water basket. Particles from the +12 and +60 fractions were stored together, while particles from the -60 fraction were returned to their original vial and sent to an independent, commercial laboratory for quantitative analysis by x-ray diffraction.

Observations

PE-0391 Nozzle 1 J16

Material consists dominantly of coal fines with subordinate quartz fines and orange limonite staining occurs on grains of coal and sandstone.

PE-0391 Nozzle 1 #3

- +12 size material consists of large, blocky coal fragments up to 1 cm in length. Material in this size fraction weighs 0.64 g.
- +60 size material consists of approximately one-third each of angular coal, bony coal, and rust flakes. The largest fragments are represented by angular coal fragments, with limonite-altered rust flakes also occurring as larger pieces. The weight of this size fraction is 0.03 g.
- -60 size material weighs 0.01 g and is insufficient in volume for analysis. Based on visual inspection, the fraction consists of up to 10% rust flakes, 10% sandstone, and the remainder represented by coal and bony coal.

PE-0391 Nozzle 1 #7

Material consists of two large rust flakes (+60 size), with several +60 size mud balls that are composed of coal fines and quartz, with sparse, angular coal fragments. Fines consist of “black dirt” that may include some coal fines, but fine grains are clumped together possibly by oil or grease.

PE-0391 Nozzle 1 Bit #8

Material consists dominantly of +60 size material, and minor -60 size material, in proportions of 5% sandstone, 10% bony coal, and 85% coal.

PE-0391 Nozzle 1 #10

- +12 size material consists of flat rust fragments that show iron oxide alteration, along with angular coal fragments that show iron oxide staining. There is also a single clast of gray, coarse-grained siltstone. The weight of this size fraction is 0.02 g.
- +60 size material consists of 85% angular fragments of fine-grained micaceous sandstone and gray coarse-grained siltstone, 10% angular coal fragments, and 5% thin flakes of heavily limonite-altered rust. Gray siltstone/sandstone exhibits freshly broken surfaces. The weight of this size fraction is 0.69 g.
- -60 size material weighs 0.5 g and was sent for XRD analysis.

PE-0391 Nozzle 1 #15

- +12 size material consists of a single fragment of bony coal, with weight below the measuring capability of the balance.
- +60 size material consists of 85% angular fragments of coal and bony coal, 10% angular sandstone fragments, and 5% rust flakes, weighing 0.22 g.
- -60 size material weighs 0.26 g and was sent for XRD analysis.

PE-0392 Nozzle 1 1-1

Material consists of +60 coal, bony coal, and dark gray siltstone fragments with very minor amounts of -60 fines. Minor rust staining occurs on a few bony coal and dark gray siltstone fragments.

PE-0395 Internal to Nozzle #1

- +12 size material consists of a single piece of coal, with the remaining pieces consisting of dark gray micaceous coarse-grained siltstone. The siltstone consists of angular, broken fragments characterized by fresh surfaces. The weight of this fraction is 0.10 g.
- +60 size material consists of 75% dark gray siltstone, 15% sandstone, and 10% coal. Some siltstone hosts carbonized plant fossil traces; some sandstone hosts iron staining. All fragments exhibit angular, freshly broken surfaces. The weight of this fraction is 0.58 g.
- -60 size material weighs 0.63 g and was sent for XRD analysis.

PE-0395 Nozzle 1 #2 Inter Portion of Housing Vial A

- +12 size material consisted of several rounded mud balls, that when lightly probed, were disaggregated into -60 size quartz silt with a single +12 fragment of coal.
- +60 size material consists of angular fragments of sandstone (50%), dark gray siltstone (40%), and coal (10%). The dark gray siltstone hosts some iron staining. This size fraction weighs 0.13 g.
- -60 size material weighs 0.25 g and was sent for XRD analysis.

PE-0395 Internal to Nozzle #2 Vial B

- +12 size material consists of rounded mud balls that, when disaggregated, are actually a composite of light-colored quartz silt that are considered as part of the -60 size fraction
- +60 size material consists of rust 5% rust, 15% coal, 30% dark gray siltstone, and 50% sandstone. Rust flakes are heavily altered to limonite and colored orange. This size fraction weighs 0.39 g.
- -60 size material weighs 0.9 g and was sent for XRD analysis.

PE-0395 Nozzle 1 #3 Inter Portion of Housing Vial A

- +12 size material consists of several large, rounded mud balls, which are easily disaggregated into fines that consist of quartz silt and coal, and are considered as part of the -60 size fraction.
- +60 size material consists of 2% rust flakes, 10% angular coal fragments, 35% dark gray siltstone, and 53% light-colored quartz sandstone. Fragments are bounded by freshly broken surfaces with rounded-off edges, suggestive of milling. This size fraction weighs 0.61 g.
- -60 size material weighs 1.09 g and was sent for XRD analysis.

PE-0395 External Sides of Nozzle #3, No Ends, Vial B

- +12 size material consists of subangular fragments of light-colored sandstone (15% and dark-gray, micaceous siltstone (85%), and weighs 0.07 g.
- +60 size material consists of angular, freshly broken fragments of coal (10%) and bony coal (5%), with 30% subrounded milled fragments of dark gray siltstone and 50% light-colored micaceous sandstone that sometimes is stained with limonite. The size fraction also contains 5% rust flakes. The weight of this fraction is 0.49 g.
- -60 size material weighs 0.96 g and was sent for XRD analysis.

PE-0395 Internal to Nozzle #3 Vial C

- +12 size material at first appears to consist of three angular granules of sandstone. However, with light probing, each "granule" easily disaggregates in a fine-grained mixture of agglomerated quartz sand that contains small particles of coal. The agglomerated material hosts imprints of flat, machined parts, similar to congealed mud. No material was actually in the +12 size fraction, but is instead considered part of the -60 fraction
- +60 size material consists of angular fragments of coal (3%), bony coal (5%), sandstone (35%) and dark gray, coarse-grained micaceous siltstone (57%). Angular fragments of sandstone and siltstone exhibit freshly broken surfaces, and exhibit some limonite staining. This size fraction weighs 0.82 g.
- -60 size material weighs 0.86 g and was sent for XRD analysis.

PE-0395 Nozzle 1 #4

Material consists of a single, large +12 fragment of bony coal with light gray sandstone adjoining and affixed to it, like a broken rock fragment. The grain is accompanied by -60 size angular fragments of coal and sandstone.

PE-0395 Nozzle 1 #10

- +12 size fraction contains no material
- +60 size material consists of 10% sandstone, 15% coal, and 75% dark gray siltstone. The sandstone hosts visible muscovite flakes and some iron staining. This fraction weighs 0.54 g.
- -60 size material weighs 0.67 g and was sent for XRD analysis.

PE-0397 Nozzle 1 #3

- +12 size material consists of a single grain of angular coal that is below the operating range of the balance.
- +60 size material consists of 15% coal, 10% bony coal, 40% sandstone, and 35% dark gray siltstone, along with two heavily limonite-altered rust flakes. Coal and sandstone fragments host orange limonite staining. The weight of this size fraction is 0.76 g.
- -60 size material weighs 0.33 g and was sent for XRD analysis.

PE-0397 Nozzle 1 #5

- +12 size material consists of a single grain of coal that is below the operating range of the balance.
- +60 size material consists of 10% coal, 5% bony coal, 20% sandstone, and 65% dark gray siltstone with a single rust flake. The sandstone hosts visible muscovite flakes, and the siltstone hosts iron staining. This size fraction weighs 0.27 g.
- -60 size material weighs 0.25 g and was sent for XRD analysis.

PE-0397 Nozzle 1 #6

- +12 size material consists of two grains, which are quartz + coal "mud balls" that when disaggregated represent -60 quartz fines and a few angular fragments of coal that are -12 in size.
- +60 size material consists of 5% coal, 15% sandstone, and 80% dark gray siltstone. Orange limonite staining is present on approximately half of all siltstone and sandstone. This size fraction weighs 0.37 g.
- -60 size material weighs 0.2 g and was sent for XRD analysis even though it is slightly below the sample size requirement. The sample was visible assessed as being composed of intermixed dark gray siltstone, sandstone, and coal.

PE-0397 Nozzle 1 #7

- +12 size fraction contains no material.
- +60 size material consists of angular fragments of coal (15%, dark gray siltstone (35%), and sandstone (50%). Sandstone is light-colored and commonly affected by iron staining. This size fraction weighs 0.66 g.
- -60 size material weighs 0.46 g and was sent for XRD analysis.

PE-0397 Nozzle 1 #9

- +12 size material consists of two grains, one of coarse-grained dark gray siltstone and the other of fine-grained sandstone, which together weigh 0.02 g.
- +60 size material consists of 10% coal, 40% sandstone, 50% dark gray siltstone, and fragments are characterized by freshly broken surfaces.
- -60 size material weighs 0.56 g and was sent for XRD analysis.

Conclusions

Sediment from the 1 North Longwall Panel shearer spray nozzles were separated into three size fractions. The +12 U.S. Standard Sieve mesh size was chosen because it is similar to the 1/16-inch diameter size of the spray nozzle orifices. Thus, any material larger than +12 could not have entered the nozzle from the outside, or been blown into the orifice by the explosion. The +60 U.S. Standard Sieve mesh size (0.250 mm) was chosen because it is similar to the 0.01-inch mesh (0.254 mm) used as screening on the water supply filter baskets. Thus, any material larger than +60 should not have been able to pass through the water basket filter screen, and must have entered the spray nozzle by some mechanism other than the water supply.

The presence of +60 and +12 size fragments in the spray nozzles may be an indication that the material entered through open nozzle ports on the shearer drum. It is significant that all of the +60 material consists of angular fragments of sandstone, siltstone, and coal, and that the fragments exhibit freshly broken, clean surfaces that are suggestive of generation by cutting activity of the longwall shearer. In contrast, quartz grains collected from the water baskets were characterized by subangular to subrounded, frosted grains that are considered typical of abrasion during transport on a geological time scale, and are likely to have been entrained in the water supply from the river or other surface supply. Individual sand grains of this nature were not observed in the +60 spray nozzle material. Furthermore, it is significant that the +60 size material contains sandstone, as well as dark gray, coarse-grained siltstone. During previous petrographic study of rock samples collected from the roof and floor of the longwall face, as part of the assessment of incendive potential, it was determined that while the immediate floor is composed of sandstone alone, the immediate roof is composed of sandstone and thin layers of siltstone, which is represented by dark gray laminations. It therefore appears that chips of sandstone and siltstone from the roof had been falling into openings in the cutting drums for some unknown period of time.

A significant conclusion of this observation is that it seems highly unlikely that the drum could have been filled with freshly cut rock chips if the spray nozzles had been removed only after the tail drum cut out as part of routine maintenance just prior to the explosion. The presence of a significant volume of the +60 material being represented by dark gray, coarse-grained siltstone is an indication of rock chips falling from the immediate roof. Therefore, the drum must have been operating with open nozzle ports, and concomitant lack of water pressure, for some unknown length of time prior to the explosion. This is not an indication that the drum was operating in the moments before the explosion, but does indicate that the drum was most likely being operated without functional water sprays in the hours or days prior to the explosion.

The presence of imprints of flat, machined surfaces on mud composed of quartz and coal fines is an indication that these fines had been caked onto the sides of the nozzles in the presence of water, forming an agglomerated mixture. “Mud balls” composed of the same material were also collected from inside the spray nozzles. The sediment collected from the nozzles contained very few actual rust flakes, generally no more than 5%. It therefore seems unreasonable to conclude that the sprays were clogged by rust that had formed in the drum upon restoration of water to the shearer during the December 2010 test. Furthermore, the goethite-altered rust flakes collected from the water baskets is of a different nature than the bright-orange limonite that apparently formed inside the drum. Although the bright orange limonite was found as thin coatings on some sandstone and siltstone fragments, it was not a constituent of the “mud balls” found within the spray nozzles. It would therefore appear that the quartz + coal fines were already present and hardened within the spray nozzles prior to restoration of water to the shearer.

Tailgate Drum Spray Nozzles

Background

On April 13-14, 2011 sediment that had been previously collected from spray nozzle ports, as well as sediment secured within spray nozzles collected by MSHA’s Accident Investigation team from UBB was described in terms of grain size and mineralogy. Although similar activity had been conducted previously for sediment collected during the course of measuring dimensions of nozzles retrieved from the headgate drum, tailgate drum, and ranging arm of the 1 North Panel longwall shearer, the activities of April 13-14 were conducted on nozzles and material collected from the tailgate drum only, after it had been rotated to expose the underside portion of the drum. Sediment had been collected in Zip-Loc baggies, and spray nozzles were taped closed and placed in baggies where plastic basal inserts were not present, and provided by members of the Accident Investigation team. Nozzles and sediment were listed under the designations PE-0464 and PE-0465.

Sediment from each vial was separated into four size fractions by passing it through three screens. The top screen was U.S. Standard Sieve Size No. 8, which corresponds to 3/32nd-inch and reflects the orifice diameter of the majority of spray nozzles utilized on the tailgate drum; the next screen was U.S. Standard Sieve Size No. 12, which corresponds to 1/16th-inch and reflects the orifice diameter of the spray nozzle stipulated in the company's approved plan; the third screen was U.S. Standard Sieve Size No. 60, which corresponds to the 0.01-inch screen size used in the longwall shearer water supply basket filters. Material finer than No. 60 mesh was collected in a pan at the bottom of the sieve array. The first sample (PE-0465, Spray Port #38) was broken into seven size fractions (+8, +12, +60, +100, +140, +200, and -200), but due to the very small volume of material present, and the virtual absence of several intervening size fractions, subsequent samples were broken into only the four previously described fractions.

Some sediment was provided loose in individual bags, while other bags contained a spray nozzle and associated staple lock. Some spray nozzles were wrapped with black electrical tape to ensure that any sediment present remained inside the nozzle. Other nozzles were not wrapped with tape but retained their original plastic insert at the base of the nozzle. In each respective case, the black electrical tape was unwrapped to first expose the nozzle outlet orifice, and the presence of any foreign matter was determined. Subsequently, the base of the nozzle was exposed by removing the tape, and a photograph of the inside of the nozzle and any material stuck to the tape was taken. If sediment was present, the stratigraphy of the sediment was noted in order to determine which sediment was deposited first and which most recently, with sediment at the base of the nozzle interpreted to have been deposited most recently. Where plastic inserts were in place, it was determined whether the orifices were clogged, and upon removal of the insert, the presence of foreign material was documented on the inside of the insert. Additionally, the presence of plastic flaps indicative of incomplete drilling was documented.

After the stack of sieves was placed on a shaker table for 10 minutes, each size fraction was weighed, and the particles in each fraction were described by spreading the particles on a clean, white sheet of paper and inspecting the particles with a 10-power lens under bright light. Upon completion of the description, each size fraction was stored separately in a glass vial marked with the PE number and size fraction. Upon completion of documentation activities, the vials were placed together in the original sample bag, containing the spray nozzle, staple, and black electrical tape or insert used to retain material inside nozzles.

Observations

PE-0465 Spray Port #10 (loose in bag) 5.57 g

- +8 material (5.15 g) consists of a single large piece of welding bead or slag (17 mm long), two pieces of dark gray siltstone (4 mm long), and ten pieces of coal (3-10 mm long). The welding slag has a light patina of rust but mostly is shiny, beaded metal.
- +12 material (0.07 g) consists of six pieces of coal/bony coal and four pieces of dark gray siltstone.
- +60 material (0.3 g) consists of round, beaded welding spatter that has a light patina of rust but is still mostly shiny metal. The fraction is dominated by angular fragments of coal (60%), with dark gray siltstone (35%) and light gray sandstone (5%). The fraction also contains a bright silver lump of metal that is soft enough to be cut with a steel knife blade, and is interpreted to represent a bead of solder.
- -60 material (0.05 g) consists of angular fragments of coal (35%), dark gray siltstone (50%), and light gray sandstone (5%) with sparsely distributed rust flakes (10%).

PE-0465 Spray Port #38 (loose in bag)

- +8 material (0.35 g) consists of a large, rectangular piece of coal that is 11 mm long, an angular piece of light gray, fine-grained sandstone with a portion of coal streak attached that is 3 mm long, and a large, flat rust flake that is 5 mm long and showing dark-colored goethite alteration. Two “mud balls” that were easily disaggregated into fines are also present.
- +12 material (0.03 g) consists of two rust flakes that are 4 mm long, and a “mud ball” that is 3.5 mm long and composed of an aggregate of fines.
- +60 material (0.4 g) is dominated by rust flakes (86%) with 10% angular coal fragments, 3% angular, dark gray siltstone, and 1% angular fragments of light gray, fine-grained sandstone. The size fraction also contains a single “mud ball” composed of fines.
- +100 material consists of angular flat, angular fragments of rust (15%), as well as angular fragments of coal (15%), dark gray siltstone (50%), and light gray sandstone (25%).
- +140 material (<0.01 g) consists of angular fragments of rust (15%), coal (20%), dark gray siltstone (50%), and light gray sandstone (15%).
- +200 material (<0.01 g) consists of angular fragments of rust, coal, sandstone, and siltstone.
- -200 material (0.02 g) consists of milled rock flour, which is dominated by dark gray siltstone and light gray sandstone that fives a salt-and-pepper color, with sparsely scattered coal but no rust.

PE-0465 Spray Port #39 (loose in bag) 1.64 g

- +8 material (0.07 g) consists of five large, angular rust flakes that are characterized by dark brown goethite alteration.
- +12 material (0.17 g) consists dominantly of rust flakes (about 12-15 in number), with two coal fragments and three fragments of dark gray siltstone. The fraction

contains one possible piece of welding slag that is hollowed out with extensive limonite alteration inside.
- +60 material (0.92 g) consists dominantly of rust flakes, with 2% dark gray, angular siltstone fragments and 5% angular coal fragments.
- -60 material (0.38 g) consists of dark and "greasy" coal fines that have a tendency to adhere to the bottom collection pan. The fraction contains angular flakes of bright orange limonite rust flakes, as well as sparsely distributed discernible angular coal fragments.

PE-0465 Port #40 (loose in bag) 1.42 g
- +8 material (0.62 g) consists of five angular fragments of coal that have had the sides and corners polished off, like in a rock tumbler. The largest fragment is 1 cm long. The fraction also contains a single rounded, bulbous metal fragment of welding slag.
- +12 material (0.03 g) consists of two rust flakes, one angular fragment of coal with fresh, sharp edges, and one angular fragment of dark gray siltstone.
- +60 material (0.51 g) consists dominantly of rust flakes (85%), with subordinate angular fragments of dark gray siltstone (10%) and coal fragments (5%) that exhibit freshly broken surfaces.
- -60 material (0.2 g) consists of orange limonite and dark brown goethite-altered rust flakes that are abundantly intermixed with a brown-tinted mixture of dark gray siltstone and angular coal fragments. The fines have a tendency to adhere to the pan and contain significant coal fines.

PE-0464 C (spray/staple) 0.15 g
When the electrical tape was unwrapped, there was no loose material inside the nozzle, although it was evident that the nozzle outlet orifice was clogged with an angular piece of coal or dark gray siltstone. Small fragments of coal and dark gray siltstone are congealed together and blocked the nozzle orifice. The inside diameter of the nozzle hosts a thick rind of agglomerated fines that represent material referred to as "mud balls" in previous observations. A few small rust flakes and angular siltstone fragments were adhered to the electrical tape where it had covered the open base of the nozzle.

- +8 material was not present
- +12 material (0.02 g) consists of a single, angular fragment of coal as well as three remnant aggregates of fines, dominantly representing coal, that formerly coated the inside of the spray nozzle. A thin, fragile rust flake was also present.
- +60 material (0.07 g) is dominated by rust flakes with very sparse angular fragments of dark gray siltstone and "mud balls" of coal fines that are remnants of the coating rind on the insides of the nozzle. The "mud balls" are easily disaggregated into fines with a slight touch.
- -60 material (0.03 g) is dominated by coal, with scattered rust flakes and dark gray siltstone.

PE-0464 D (spray/staple) 0.5 g

When the electrical tape was unwrapped, it was evident that the nozzle orifice was plugged with sediment. Upon removal of the tape across the base of the nozzle, it was evident that loose rust flakes were trapped inside the nozzle. After the loose rust flakes were dumped out, there was still congealed material inside the nozzle on the inner surface of the plugged orifice. The sediment was removed in stages: at the base of the nozzle, loose rust flakes represent the most recent material deposited, while the material farthest in the innermost recesses of the nozzle, consisting of milled sandstone and coal fines, represent material that had been deposited first, prior to the introduction of the rust flakes.

- +8 material (0.13 g) consists of one angular, blocky fragment of coal and one angular, milled fragment of light gray sandstone.
- +12 material (0.07 g) consists of one angular fragment of light gray sandstone, two angular fragments of dark gray siltstone, and five angular fragments of coal, some of which exhibit light, surficial iron staining.
- +60 material (0.22 g) consists of 5% angular fragments of light gray sandstone, 10% angular fragments of dark gray siltstone, 15% coal, and 70% rust flakes.
- -60 material (0.04 g) is dominated by light gray sandstone and dark gray siltstone with minor coal and sporadic orange limonite-altered rust flakes.

PE-0464 E (spray/staple) 0.43 g

When the electrical tape was unwrapped, angular rust flakes were revealed in the interior of the nozzle, with many flakes stuck to the tape. After several seconds of aggressive tapping, angular rust flakes remained congealed together inside the nozzle. The mass was removed by pushing a stiff wire through the orifice, which induced the disaggregation of the mass of rust flakes.

- +8 material (0.03 g) consists of two angular fragments of coal that are 4 mm in length.
- +12 material (0.05 g) consists of one angular fragment of light gray sandstone, three angular fragments of dark gray siltstone, a single angular fragment of coal, and two flat rust flakes. The rust flakes were characterized by dark brown goethite alteration with patchy orange limonite.
- +60 material (0.29 g) consists of 1% light gray sandstone that exhibits some iron staining, 2% angular coal fragments, and 97% rust flakes.
- -60 material (0.04 g) is dominated by rust flakes, with 10% angular coal fragments.

PE-0464 #10 (spray/staple) 0.02 g

There was no tape on this nozzle, although the basal plastic insert was in place. It was evident that the outlet orifice was not clogged, but that all three holes in the plastic insert at the rear of the nozzle were filled with fines. Although there is some minor coating of coal dust inside the nozzle, there was no appreciable material inside the nozzle. Two of the three holes on the inner surface of the plastic insert have “hanging chads” and the third hole was drilled cleanly but still clogged. The inside surface of the plastic insert was coated with coal dust. The very slight amount of material consisted of -60 mesh coal fines.

<u>PE-0464 #35 (spray/staple) 0.51 g</u>
When the electrical tape was unwrapped, it was evident that the nozzle outlet orifice was clogged with small, angular fragments of dark gray siltstone that abut against each other along angular corners. Upon removal of tape from the open bottom, it was evident that the inside of the nozzle was packed with fine-grained sediment that had been aggregated and completely filled the inside of the nozzle. The packed material consists of dark brown fines and angular fragments of coal and dark gray siltstone, but no rust flakes.

- +8 material (0.16 g) consists of two angular fragments of coal and four angular fragments of dark gray siltstone.
- +12 material (0.07 g) consists of three angular fragments of dark gray siltstone and five angular fragments of coal, with the corners rounded off.
- +60 material (0.14 g) consists of 5% rust flakes, 30% coal, and 65% dark gray siltstone. Rock fragments exhibit angular, freshly broken surfaces.
- -60 material (0.08 g) consists of bright orange limonite rust flakes (10%), light gray sandstone (5%), and coal fines with dark gray siltstone (85%). The fraction contains coal dust that is "greasy" and adheres to the pan.

<u>PE-0464 #38 (spray/staple) 0.8 g</u>
When the electrical tape was unwrapped, it was evident that a small rock chip was lodged in the nozzle orifice. Upon removal of the tape covering the open bottom of the nozzle, it was evident that the inside of the nozzle was packed with fine-grained rock flour that constitutes the "mud balls" collected from other sprays. The material was dislodged with a stiff, thick wire and required significant force to push through. The fines have partially lithified into a pseudo-rock and are not easily disaggregated when in-place.

- +8 material (0.27 g) consists of two angular fragments of light gray sandstone, which exhibit sharp edges and angular corners.
- +12 material (0.03 g) consists dominantly of "mud balls" that represent the pseudo-lithified fines found inside the spray nozzle, but are easily disaggregated into fines with slight pressure after being shaken. The only real +12 material consists of three angular fragments of coal, and the "mud ball" material was added to the -60 fraction.
- +60 material (0.19 g) consists of angular fragments of light gray to white sandstone (10%), dark gray siltstone (30%), and coal (58%) that exhibit freshly broken surfaces, as well as "mud balls" that have been rounded off during shaking. The "mud balls" represent the pseudo-lithified fines that are easily disaggregated. The fraction also includes very rare rust flakes (2%).
- -60 material (0.28 g) consists dominantly of fines from the disaggregated, pseudo-lithified deposits on the inside of the nozzle. Discernible pieces are angular

fragments of coal and dark gray siltstone. The fines include the “mud ball” material from the +12 fraction.

PE-0464 #42 (spray/staple) no material
There was no tape on this nozzle, although the basal plastic insert was in place. It was evident that the outlet orifice was not clogged, but that all three of the holes in the plastic insert were clogged. Upon removal of the insert, it was evident that there was no material inside the nozzle. Inspection of the inner surface of the plastic insert indicated that the center hole was clogged, and that it is the only hole with a “hanging chad.” Inspection of the outer surface indicated that all three holes were filled with coal fines and angular fragments of dark gray siltstone.

PE-0464 #43 (spray/staple) 0.13 g
There was no tape on this nozzle, although the basal plastic insert was in place. It was evident that the outlet orifice was not clogged, and that of the three holes in the plastic insert, one was clogged with coal fines and one (central hole) was clogged with a shiny, metallic bead that is indicative of welding spatter. Upon removal of the plastic insert, it was apparent that the rear (inside surface) of the holes had flaps of plastic still attached, similar to a “hanging chad” that had impeded the passage of sediment through the hole. An angular fragment of dark gray siltstone, as well as a metal bead had been trapped by the “hanging chads.”

- +8 material (0.1 g) consists of a single, rounded, shiny metallic piece that represents a welding bead, with some yellow brass or brazing on one part. The rounded ends are shiny metal, while the intervening part shows rust oxidation.
- +12 size fraction contains no material
- +60 material (<0.01 g) consists of 5% rust flakes, 35% angular coal fragments, and 60% angular fragments of dark gray siltstone.
- -60 material (<0.01 g) consists of 5% rust flakes, 25% dark gray siltstone, and 70% coal fragments and coal fines.

Conclusions
Sediment from the 1 North Longwall shearer’s tailgate drum spray nozzles were separated into four size fractions. The No. 8 and No. 12 U.S. Standard Sieve mesh sizes were chosen because they are similar to the 3/32nd and 1/16th -inch diameter sizes of spray nozzle orifices used on the tailgate drum. Thus, any material larger than +8 or +12 could not have entered the respective nozzle from the outside. The No. 60 U.S. Standard Sieve mesh size (0.250 mm) was chosen because it is similar to the 0.01-inch mesh (0.254 mm) used as screening on the water supply filter baskets. Thus, any material larger than +60 should not have been able to pass through the water basket filter screen, and is more likely to have entered the spray nozzle by some mechanism other than the water supply.

The presence of +60, +12, and +8 size fragments in the spray nozzles may be an indication that the material entered through open nozzle ports on the shearer drum. It is significant that all of the +60 material consists of angular fragments of sandstone, siltstone, and coal, and that the fragments exhibit freshly broken, clean surfaces that are suggestive of generation by cutting activity of the longwall shearer. In contrast, quartz grains collected from the water baskets were characterized by subangular to subrounded, frosted grains that are considered typical of abrasion during transport on a geological time scale, and are likely to have been entrained in the water supply from the river or other surface supply. Individual quartz grains of this nature were not observed in any of the spray nozzle material. Furthermore, it is significant that the +60, +12, and +8 size material contains light gray to white sandstone, as well as dark gray, coarse-grained siltstone. During previous petrographic study of rock samples collected from the roof and floor of the longwall face, as part of the assessment of incendive potential, it was determined that while the immediate floor is composed of sandstone alone, the immediate roof is composed of light gray sandstone and thin layers of siltstone, which is represented by dark gray laminations. It therefore appears that chips of sandstone and siltstone from the roof had been falling into openings in the cutting drums for some unknown period of time.

A significant conclusion of this observation is that it seems highly unlikely that the drum could have been filled with freshly cut rock chips if the spray nozzles had been removed only after the tail drum cut out as part of routine maintenance just prior to the explosion. The presence of a significant volume of the +60 material being represented by dark gray, coarse-grained siltstone is an indication of rock chips falling from the immediate roof. Therefore, the drum must have been operating with open nozzle ports, and concomitant lack of water pressure, for some unknown length of time prior to the explosion. This is not an indication that the drum was operating in the moments before the explosion, but does indicate that the drum was most likely being operated without functional water sprays in the hours or days prior to the explosion.

The insides of several spray nozzles contained a rind of agglomerated coal fines and rock flour that in some cases had dried to a cement, and required significant force to dislodge. This material had in some cases coated the inside of the nozzle, clogging the outlet orifice especially where angular fragments of coal or siltstone had already become stuck inside the orifice. Although the nozzles in this batch of samples generally contained more rust flakes than the previous nozzles, and those rust flakes were of the +60/-12 fraction, the rust flakes occupied the basal portion of the spray nozzle interior, indicating that the coal/rock flour cement had been deposited first and clogged the spray, with the rust flakes deposited at some later time. In contrast to the sediment collected from the previously studied nozzles, which contained generally no more than 5% rust flakes, the nozzles collected from the bottom of the drum hosted a significant volume of rust flakes in the +60/-12 size fraction. This would suggest that the rust flakes preferentially settled to the bottom of the drum. However, it is not clear that the rust flakes were introduced during the restoration of water to the shearer in December 2010, because they should not have been able to pass through the water basket screen. Rust fragments are characterized by thin, flat flakes with a dark brown coloration and metallic luster, indicating the initial stages of oxidation to form lepidocrocite and goethite. This rust is of a different nature than the bright-orange, amorphous limonite staining that forms coatings on some angular rock chips collected from the spray nozzles and collected in a 20-ounce bottle by members of the Accident Investigation team during the December 2010 restoration of water to the shearer. Although the timing of rust introduction is unknown, it was definitely introduced after the coal/rock flour cement had already clogged the spray nozzles.

A significant amount of foreign material in the form of welding spatter and welding slag was present in this subset of nozzle samples, likely reflecting the propensity of high-density material to settle to the bottom of the drum. Welding spatter exhibited shiny, polished surfaces that are interpreted to reflect abrasion from the numerous rock fragments entrained inside the rotating drum, producing a scouring action similar to a ball mill. Welding spatter in some cases had clogged the spray nozzle outlet orifices, and become lodged in the holes of the plastic inserts.