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UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

COAL MINE SAFETY AND HEALTH

REPORT OF INVESTIGATION

Surface Facility

Exploding Vessels Under Pressure Accident

February 6, 2013

at

Five Mile Prep Plant & Refuse Impoundment
Midland Trail Energy, LLC
Tad, Kanawha County, West Virginia
I.D. No. 46-09226

Accident Investigators

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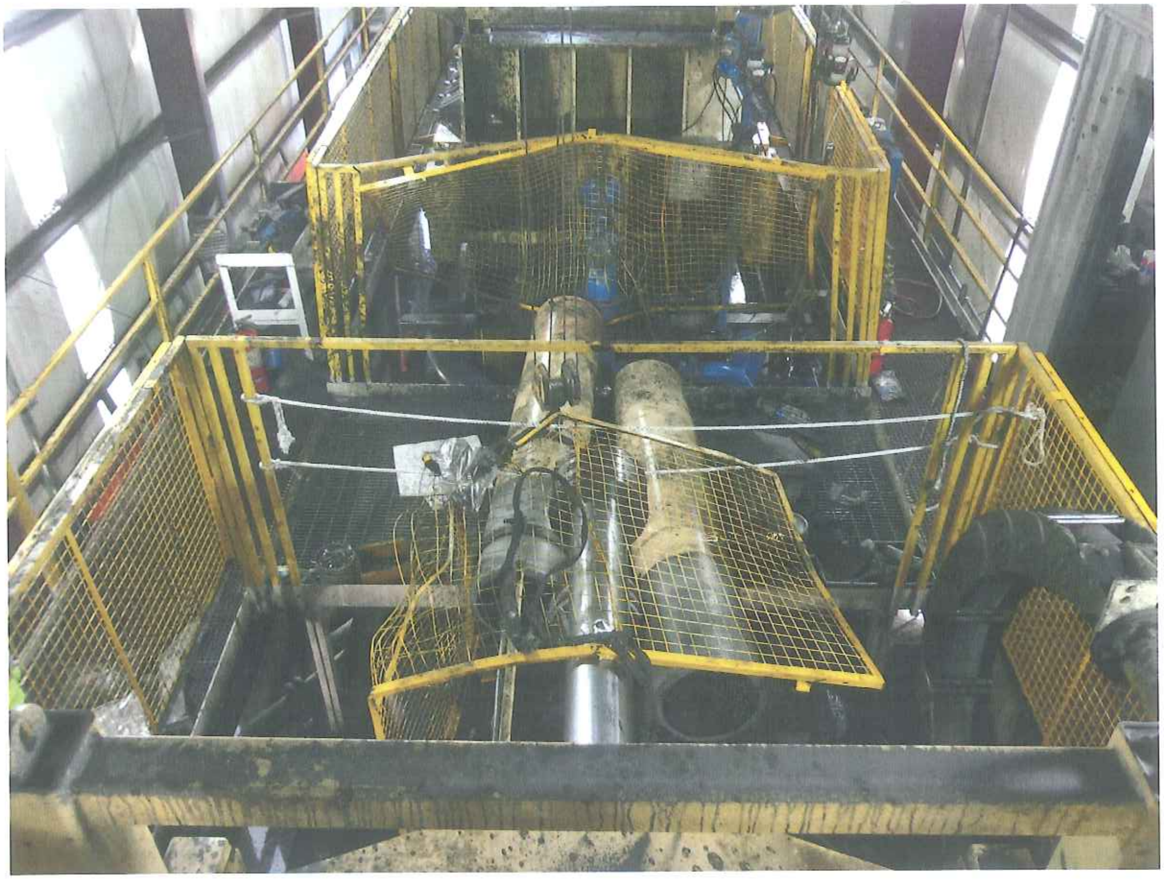


OVERVIEW

At approximately 4:00 p.m. on Wednesday, February 6, 2013, Brandon E. Townsend, a 34-year-old electrical processes specialist with over nine years of mining experience, was fatally injured at the Five Mile Preparation Plant & Refuse Impoundment Facility. The accident occurred while the victim and other workers were troubleshooting a membrane filter press that is used to de-water fine coal refuse material that is collected as part of the coal cleaning process. Two large hydraulic cylinders on the A-Press suddenly and catastrophically failed while the press was in operation, causing portions of the cylinders to propel away from the machine and into the walkway where Townsend was located. The broken hydraulic cylinder barrels shot into the walkway, displacing the machine's area guard and striking Townsend, causing multiple traumatic injuries which resulted in his death.

GENERAL INFORMATION

The Five Mile Preparation Plant & Refuse Impoundment is a coal preparation facility located near Tad, Kanawha County, West Virginia. Midland Trail Energy, LLC, is the operator of the facility and Patriot Coal Corporation, located in St. Louis, Missouri, is the parent company of Midland Trail Energy, LLC. The principal officers for the facility at the time of the accident were:

Gregory Dotson..General Manager
David Kimbrell.. Plant Superintendent
Roy Gibson ....Day shift Plant Foreman
Aaron Price ....Manager of Safety

The plant processes an average of 10,000 tons per day of raw coal from two adjacent underground mines. Employment is provided for 28 miners, working a schedule of two shifts per day, six days per week. There is not a specific shift designated for maintenance work only. Raw coal is transported to the plant stockpile area by off-road coal trucks. The raw coal is then fed into the plant by a bulldozer, which pushes the material into an underground feeder, where a conveyor system delivers it to the plant for processing.

Prior to the accident, the Mine Safety and Health Administration (MSHA) completed its last regular safety and health inspection of this facility on January 22, 2013. The Non-Fatal Days Lost (NFDL) injury incidence rate for this facility in 2012 was 0.00, compared to a National NFDL rate of 3.58 for the same period.

DESCRIPTION OF THE ACCIDENT

The day shift began prior to 6:00 a.m., with Roy Gibson, Plant Foreman, performing a pre-shift examination, first of the press building and then of the preparation plant building. No hazardous conditions were observed nor recorded for this examination. With his shift starting at 6:00 a.m., Jeffrey "Ted" Smith, Day Shift Press Operator, met with Tom Hull, Night Shift Press Operator, about the operation of the two filter presses during the previous shift. Hull indicated to Smith that the B-Press had an intermittent issue with stopping during its pressing cycle. Hull told Smith that B-Press stopped while pressing up and began its feed cycle prematurely. Hull resolved the issue by manually pausing and then restarting the B-Press in order for it to complete the cycle. Hull mentioned no inconsistencies with the operation of the A-Press during his shift.

As a normal part of his shift, Smith began to operate the presses via the human machine interface (HMI) computer which controls the presses by a control screen in the press building control room which is connected to the programmable logic controller (PLC) system in the motor control center (MCC) room. The operation continued without incident until approximately 11:00 a.m., when slurry began to spray heavily out of the top of B-Press during its feed cycle. Slurry sprayed from the B-Press with sufficient force to tear insulation from the ceiling of the press building. Smith, who was working on "dropping cakes" (removing dewatered or compressed refuse material from between press plates as the press opens) out of the A-Press, paused the machine and went quickly to the control room to pause the B-Press. A large amount of slurry had sprayed from the machine, covering Smith also. After pausing the B-Press, Smith returned to complete the dropping of cakes from the A-Press.

Upon completion of the drop cycle on the A-Press, the slurry feed pump unexpectedly started while the press was still in an open position, which was not the normal operating sequence. Slurry began to spray into the A-Press, while the membrane plates were not pressed together. This event caused Smith to quickly pause the A-Press and report the malfunction to David Kimbrell, Plant Superintendent, via a company radio.

Smith returned to the control room with both presses still paused. While waiting for Kimbrell, Smith noticed the control screen indicated that the B-Press was in the pressing cycle. Smith knew this was incorrect, as slurry was feeding into the machine when the blow-out occurred.

When Kimbrell arrived at the press control room, Smith told him he had lost control of both presses and he expressed frustration regarding the press problems. Smith left Kimbrell at the control room and joined Travis Shamblin, Plant Technician, to help wash down the walls and clean-up the slurry spill. Upon hearing about the spill on the company radio, Bobby Phalen, Property Manager, phoned Dwight Given, Maintenance Manager, informed him of the press problems and requested his assistance. Phalen traveled to the press building to assist with the clean-up and Gibson arrived to help Kimbrell and Phalen. Smith returned to the press control room and expressed his frustration to Gibson over the loss of control of the presses. Smith told Gibson that he needed a break and Gibson concurred. Smith got his lunch box and went to the employee change trailer to change clothes. Kimbrell, Phalen, Shamblin, and Gibson went to the mine office to take a lunch break.

Following the lunch break, Gibson went to the change trailer to check on Smith who had not returned from lunch. Smith, visibly upset and covered in slurry, confronted Gibson once more about the loss of control of the two presses and slurry blow-outs that had been occurring. Gibson asked Smith if he would like to go home. Smith left the property just before 1:00 p.m.

Upon returning to the press building, Gibson asked Shamblin if he would operate the presses since Smith had left the property. Shamblin agreed and went with Kimbrell and Phalen to restart the B-Press. Gibson temporarily left the press building and traveled to the plant to address other unrelated issues with the plant decanter. When the B-Press was restarted, it once again sprayed slurry. The B-Press was opened and a torn filter cloth on one of the plates was found and replaced. The B-Press was then restarted only to find another leak. Gibson returned from the plant and began to help diagnose the problem with the B-Press, spraying water to wash off the individual plates of the machine, as Shamblin and Phalen spread the plates apart in the area of the leak.

While clean-up work continued on the B-Press, Given arrived to assist in troubleshooting the problems that were occurring with the two presses. Given suggested it might be helpful to reset the power to the PLCs for both presses since the PLCs control the automation and sequencing of the filter press system. Given reset the power to the PLCs by opening and closing the related circuit breakers. Resetting power did not resolve the problems. Given went to the plant office and attempted to call Hulin Cook Jr., Senior Manager of Power and Automation, Noah Toney, Electrical Control Specialist, and Brandon Townsend, Specialist of Electrical Processes. Given was unable to contact any of the three men and instead left voice mail messages for them at approximately 12:30 p.m., informing them of the press problems.

Kimbrell called Joe White, Preparation Plant Engineer, who was at the nearby Kanawha Eagle Preparation Plant, and described the press problems to him. White left Kanawha Eagle Preparation Plant to assist Kimbrell. While traveling to the press building, White called Cook, who was in Kentucky, and asked him to call Given. Cook called Given and discussed the press problems. Meanwhile, Townsend received Given's voice message and returned his call, letting him know that he was also on his way to the site.

Given was able to make contact with Toney, who was at another location. Toney began to monitor the PLC program remotely in order to assist in the troubleshooting of the presses. Kimbrell, troubleshooting from the press building control room, relayed messages to Given (via company radio) who then relayed them to Toney over the telephone. White arrived on property at approximately 1:47 p.m., traveled to the press building, and assisted Gibson and Phalen in troubleshooting the B-Press. Another attempt was made to operate the B-Press and again another slurry leak was found. White went to the plant office to discuss the issues with Given concerning the B-Press. White told Given they thought the problem with the B-Press involved torn filter cloth.

White and Kimbrell decided to check-out the A-Press while the filter cloth was being changed on the B-Press. Townsend arrived on site at approximately 2:49 p.m., and traveled to the press building. Townsend met with White, Kimbrell, and Phalen, and they briefly discussed the problem they were experiencing with the A-Press, namely that the feed cycle started out of sequence. Townsend traveled to the MCC room and set-up his laptop computer.

Phalen returned to the mine office and told Given that Townsend was on site. Given proceeded to the press building and met Townsend. Given and Townsend entered the press building together and went up to the second floor. Kimbrell also met Given and Townsend at the top of the stairs and told them they needed to get the A-Press back to the beginning of the cycle. Kimbrell anticipated a potential slurry leak and asked Given to sit at the control room computer in order to pause the machine should something go wrong. The A-Press was manually closed and then switched to the automatic mode so that it could complete its normal cycle. The A-Press continued its automatic cycle, feeding the slurry, compressing the material, and then began to open as normal in order to drop out the cakes without incident. White traveled down the off-side walkway toward the feed end of the A-Press. Townsend followed Kimbrell down the opposite walkway from the control room toward the feed end of the A-Press as it began to open.

With White on the off-side walkway and Kimbrell and Townsend on the control room side walkway, the men began dislodging the caked material from between each plate, using boat paddles to dislodge the cakes, slowly working their way back toward the cylinder end of the A-Press, observing it as it opened. This cycle was completed without incident and the next cycle began automatically as the hydraulic pump started and the hydraulic cylinders began to extend, closing the A-Press. Kimbrell and Townsend continued toward the control room. Kimbrell turned right and stepped into the control room doorway to watch the control screen with Given.

Townsend turned left into the walkway between the A-Press and the B-Press, stopping behind the hydraulic cylinders of the A-Press (see Appendix C), in order to examine the hydraulic pressure gauge mounted on top of the upper cylinder (about at eye level) of the A-Press. At approximately 4:00 p.m., while Townsend was standing in the walkway between the two presses, examining the pressure gauge, there was a sudden and catastrophic failure of both hydraulic cylinders.

In an instant, the broken cylinder barrels (weighing over 2,000 pounds each), shot into the walkway, crashing into the end guarding and thrusting it against Townsend, driving him back, approximately 7-8 feet, into adjacent guarding and piping on the B-Press. He was caught between the two sections of displaced guarding and pinned against the adjacent press by the hydraulic cylinder barrels where he sustained multiple traumatic injuries which led to his death. Simultaneously, White was struck in the face. The blow left White lying on the walkway with serious injuries including a broken jaw and missing teeth.

Kimbrell was standing in the control room doorway and was sprayed from behind with hydraulic oil as he heard the sudden failure of the press. Kimbrell turned around and rushed to the aid of Townsend. As Kimbrell was attending to Townsend, he noticed movement on the opposite side of the presses and observed White standing up with a laceration on his chin. Kimbrell asked White if he was alright and White acknowledged him. White (injured, stunned and unaware of Townsend's location), traveled downstairs and outside to the mine office to assess his injuries. Kimbrell was unable to fully reach Townsend for assessment due to the position of the damaged guarding, so he asked Shamblin, who arrived from working on the B-Press, to hold Townsend upright while he went around the machine. Shamblin held onto Townsend's shoulder, holding him upright while Kimbrell ran around the machine. Phalen immediately went to call for help. Kimbrell switched places with Shamblin and was unable to get a response or pulse from Townsend. Gibson arrived from working on the B-Press and was also unable to get a pulse from Townsend. Townsend was suspended in a precarious position as he was pinned by the cylinder barrel and guarding beyond the walkway, suspended approximately 15 ½ feet above the concrete floor.

Malden Fire Department was notified at 4:04 p.m., and arrived on scene at 4:23 p.m. Upon arrival, the firemen quickly assessed Townsend and found that he had no pulse and was unresponsive. The county medical examiner arrived at 5:40 p.m., and recorded his time of death to be 4:28 p.m. Malden Fire Department carefully extricated Townsend, utilizing an overhead crane in the press building to move damaged components. Upon extrication, Townsend was transported by the Kanawha County medical examiner and arrived at the Office of the Chief Medical Examiner in Charleston, West Virginia at 7:43 p.m.

White awaited medical attention in the plant office. Assistance was provided to White by plant employees to help control bleeding. White was transported by Cedar Grove Fire Department, to CAMC General Hospital where he was treated and later released.

INVESTIGATION OF THE ACCIDENT

Greg Dotson, General Manager, notified MSHA of the accident at 4:11 p.m., on February 6, 2013, via a telephone call to the MSHA notification hotline. MSHA's District 4 Office was notified at 4:24 p.m. The accident was referred to MSHA's Mount Carbon Field Office. Byron Tucker and Michael Boggs, Coal Mine Safety and Health Inspectors, were sent to the facility.

A 103(j) Order was verbally issued to Dotson at 4:38 p.m., to prevent destruction of any evidence which would assist in investigating the cause or causes of the accident. Vincent Nicolau, Accident Investigator, was notified of the accident at 4:40 p.m., and traveled immediately to the Mount Carbon Field Office. Nicolau and Shane Adkins, Supervisory Coal Mine Safety and Health Inspector, immediately departed to the scene.

Tucker and Boggs arrived on mine property at 5:51 p.m. and 6:10 p.m., respectively, and traveled to the press building. Upon arrival, Tucker reduced the 103(j) order to writing and modified it to proceed under the authority of Section 103(k) of the Federal Mine Safety and Health Act of 1977. Nicolau and Adkins arrived on mine property at 6:30 p.m., and traveled to the press building where they met with Accident Investigators from the West Virginia Office of Miners' Health Safety and Training (WVOMHS&T). Upon entering the press building, the bottom floor was covered in slurry and hydraulic oil, approximately ankle deep. Malden Fire Department was observed completing their removal of the victim's body. Nicolau examined the accident scene for hazards and traveled to the mine office where brief informal interviews were conducted with Kimbrell and Given who were closest to the victim when the accident occurred. Written statements from other employees were also obtained. Tucker and Boggs remained in the press building to assist in gathering information and photographs. Following the informal interviews, Nicolau accompanied WVOMHS&T investigators and company personnel to the accident scene for additional examinations and photographs.

The accident investigation continued on the morning of February 7, 2013. Tucker returned to the facility and modified the 103(k) order to include the area of the adjacent MCC room and all electrical circuits associated with the press building. Nicolau traveled to the accident scene and met with Tucker who had modified the 103(k) order at 1:15 p.m., to include these additional areas. Additional photographs were taken of the accident scene. A modification request was presented by the operator to pump the water, slurry, oil, etc., from the bottom floor of the press building and turn on the building heaters. The modification was granted and issued by Tucker at 6:45 p.m. Shortly thereafter, Jonathan Hall and Eugene Hennen, both Mechanical Engineers from MSHA's Approval and Certification Center, arrived on site to assist in the accident investigation.

Formal interviews were jointly conducted on February 13, 14, and 25, 2013, with persons who had knowledge relevant to the accident. Those persons who were interviewed and/or participated in the investigation are listed in Appendix A. The investigation was conducted with the assistance of the mine operator, miners, and the WVOMHS&T.

DISCUSSION

Accident Site

The accident occurred on the second floor of the press building, between the two membrane filter presses. The second floor walkway surrounding the presses consists of 36-inch wide open bar grating with steel banding, or toe boards, with typical handrails installed around the perimeter of the walkway. The walkway between the two presses is also constructed of open bar grating and is supported by structural steel which is supported by concrete piers. This walkway is 74 inches wide and 142 inches in length when facing the press control room (see Appendix C). The area guarding surrounding both presses consists of removable sections of steel angle frames, covered with welded wire mesh. These guards are 63 ½ inches tall and are installed to prevent exposure to moving parts.

Filter Press Operation

As raw coal is processed and washed in the preparation plant, coal slurry (fine coal refuse and water), is collected and pumped into the adjacent press building for dewatering. The press building contains two membrane filter presses (Jing Jin, Model 2000 X 2000 X 40), which are used to dewater the slurry. These two membrane filter presses, the A-Press and the B-Press, utilize a unique filtering process which involves hydraulic pressure, slurry pumps, filtering membranes, and compressed air to remove water from the slurry material. The filtering cycle begins as concave plates, covered in filter cloth (membrane), are pressed tightly together by hydraulic pressure to create a partially pressurized vessel. Slurry is then pumped through an opening in the center of the plates, where it fills and pressurizes the spaces between the plates. As these spaces fill with slurry, slurry pump pressure forces water through the filter cloth on each membrane plate, reducing the water content of the slurry. When slurry capacity is reached, air pressure is applied to every other plate to place further pressure on the slurry and change the thin liquid into a damp solid called "cake." As the slurry is pressed, water is collected and recycled back into the plant circuit. As the machines open, the cake falls onto a conveyor where it is carried to a storage bin and then hauled by truck to a refuse disposal area.

Mechanical and Hydraulic Examination

Thorough examinations of the mechanical and hydraulic components involved in this accident were conducted by MSHA and the WVOMHS&T, along with hydraulic experts, mechanical engineers, and Constellation Technology, an independent analytical services laboratory. Based on interviews and testing of system components, the following is a discussion of the resulting observations, and the thorough examination of the equipment involved in this accident.

Witness testimony indicates that the hydraulic pressure gauge/switch (see Appendix D) located on top of the upper hydraulic cylinder of the A-Press failed to function properly immediately prior to the failure of the cylinders. Several persons interviewed confirmed that they did not hear the hydraulic pump shut off or stop running immediately prior to the accident. When examined and tested following the accident, the upper limit switch contained in this gauge/switch failed to make contact several times. The upper limit switch functioned properly only after it was manually forced to make contact by investigators during testing. Information obtained in the interview process also shows that the upper hydraulic limit setting of the gauge was reduced on several occasions in an effort to make the hydraulic pump motor stop. While the pressure gauge/switch did sustain some apparent damage as a result of the accident, the low limit switch functioned properly when tested. The failure of the upper limit switch contributed to the accident.

The failure of this upper limit switch would cause the hydraulic pump to increase hydraulic pressure in the cylinders beyond the manufacturer's recommended operating pressure of 2,312 psi. This would not normally create a problem since the main system hydraulic relief valve, as supplied by the manufacturer, is factory set and tested by the manufacturer to relieve pressure at 22 MPa or 3,190 psi., which is below the maximum pressure that the cylinders are designed to withstand. This preset pressure was verified by testing the main system relief valve on the B-Press which was found to be properly adjusted. Following the accident, it was observed that the upper limit setting of the pressure gauge/switch for the A-Press had been turned down by the mine operator and was set at approximately 12.8 Megapascals (MPa) or 1,856 psi.

However, the main system hydraulic relief valve on the A-Press had been adjusted and was set at 4,800 psi. MSHA accident investigators were not able to determine who adjusted this relief valve. Failure of the upper limit switch would normally cause the hydraulic pump to reach 3,190 psi (the factory setting for the hydraulic relief valve) and then relieve any excess pressure back to the hydraulic tank. The press manufacturer recommends a maximum pump supplied operating pressure for the cylinders of 2,312 psi. Since the relief valve was improperly adjusted, and the upper limit switch likely failed to operate, the A-press hydraulic system would be subjected to pressures higher than those recommended by the manufacturer. Improper adjustment of this valve combined with intermittent failure of the upper limit switch would cause the A-Press to be periodically subjected to more than double the manufacturer's recommended operating pressure. These conditions accelerated the fatigue damage in the cylinders.

Electric motors supplying power to the hydraulic pumps for both presses had periodically been overloaded to the point that they tripped their dedicated circuit breakers. This was confirmed by reviewing work order documents and through interviews. Overloading of the electric motor would occur when the upper limit hydraulic pressure switch failed to function, causing the hydraulic pump to supply pressure up to the relief valve setting. Information obtained in the interview process also showed that the circuit breaker for the A-Press was reset on several occasions, as much as nine months prior to the accident. This indicates that the A-Press was periodically subjected to higher than normal hydraulic pressures for several months prior to the accident.

The upper limit switch in the gauge/switch on the A-Press was adjusted multiple times, by different individuals, to get the hydraulic pump to shut-off or stop. It was also revealed that the press operators would periodically pause the press because the pump would not stop running. The investigation and interview process revealed that the tripping of the circuit breaker and associated pump motor issues were not limited to the A-Press. Similar events were reported for the B-Press as well. It should be noted that the B-Press hydraulic pump was replaced in April 2012 due to failure. The mine operator failed to identify and investigate the actual cause of the tripping of the circuit breaker on either press.

Hydraulic Cylinder Observations

Upon examination and testing of the failed hydraulic cylinders, a number of facts of concern were discovered involving the design and manufacture of the cylinders. The design of the cylinders created significant stress concentrations in two places.

A stress concentration is an element of a design that magnifies the effect of a force placed on the material as the force passes through that element. Stress concentrations increase the stress felt by the material in a small area around where the stress concentration occurs. These concentrations are not accounted for in traditional engineering calculations which assume uniform stresses throughout a component.

The first stress concentration was created when the end of the seamless tube used to make the cylinder barrels was machined where the mounting flange would be attached. The second stress concentration was formed where the mounting flange was welded onto the cylinder barrel.

The most common type of stress concentration results from an abrupt change in width or diameter. Engineering handbooks provide tables to calculate stress concentrations based on ratios of the dimensional changes involved. The use of a radius between perpendicular portions of the design reduces the stress concentration factor. The design of these cylinders did not use any radius to transition from one diameter to another in the area where the barrel was machined for fitment of the mounting flange and where the mounting flange was welded to the barrel. Due to the lack of a radius in the transitions, the stress concentration factor in this area is higher than can be calculated by traditional methods.

In addition, the cylinders were not manufactured according to the design provided by the manufacturer. The bolt holes necessary to fasten the cylinder cap to the cylinder barrel/mounting flange weldment were drilled deeper than specified on the supplied drawings. The holes extended into the wall of the cylinder body close to where the cylinder barrel was machined without a radius and very near where the mounting flange was welded onto the cylinder barrel. The presence of these holes reduced the amount of material available to carry the forces present in the cylinder barrel at the place that those forces were magnified by two stress concentrations.

The steel standard specified by the manufacturer requires a minimum material yield strength of 835 MPa (121,075 psi). Testing of the failed cylinder barrels by Constellation Technology showed the actual material yield strength of 58,705 psi for the top cylinder barrel and 60,661 psi for the bottom cylinder barrel.

A factor of safety is a ratio between the strength of a material and the forces placed on that material. The factor of safety intended by the manufacturer, based on the specified steel and calculations provided by the manufacturer provide for a factor of safety of 3.34, before fatigue damage. The same calculations using actual material properties provided a factor of safety of 1.62 for the top cylinder barrel and 1.67 for the bottom cylinder barrel. The difference in these calculations show that these cylinders, as supplied from the factory, had 48 percent and 49 percent, respectively, of the manufacturer's intended factor of safety.

Hydraulic Cylinder Discussion

When examined, both hydraulic cylinders on the A-Press evidenced severe fatigue damage, having been in operation for only eighteen months. This extensive fatigue cracking resulted in a reduction in cylinder barrel wall thickness in many locations. In certain locations, cylinder wall thickness was reduced by as much as 45 percent. This was likely due to a combination of exposure to high hydraulic pressures, insufficient design calculations and material strength, which was significantly below the requirements of the material standard. Due to this fatigue damage, the service life (number of cycles to failure) of the cylinders was shortened.

It was estimated that the cylinders failed after 15,000 to 20,000 cycles. The effects of applying a stress which approaches the ultimate strength of the material through multiple cycles meant that over time the usable strength of the cylinders would have been reduced. When this reduced material strength equals the force placed on the material, failure occurs. This is similar to bending a paper clip back and forth until it breaks. Metallurgical testing of the cylinder barrels revealed that due to the amount of fatigue damage on the cylinders, the hydraulic pressure at failure, for the less damaged of the two cylinders (bottom cylinder), was calculated to be 2,483 psi. This means that the top cylinder failed first, at a pressure below 2,483 psi. According to calculations provided by the manufacturer, hydraulic cylinder failure (yielding) due to hydraulic pressure, would begin above 5,418 psi (37.5 MPa). Due to fatigue damage, the cylinders failed at less than 45 percent of the expected yield.

The loss of cylinder barrel wall thickness from fatigue damage was combined with the use of substandard steel. Portions of the cylinder barrel were overloaded and could no longer carry their portion of the forces placed on the cylinder. Since the cylinder barrel was not fatigued uniformly, portions of the barrel stretched more than others, potentially leading to visible movement of the cylinder barrels.

Noticeable movement (bending) of the A-Press hydraulic cylinders was likely a result of the increased (higher than recommended) hydraulic pressures combined with head frame flexing. Bending stresses were not addressed in the cylinder calculations provided by the manufacturer. However, bending of the hydraulic cylinders was observed by press operators and plant management.

Movement at the gauge end of the hydraulic cylinders on the A-Press, primarily the top cylinder, was observed by multiple employees and reported to plant management. This movement was observed and acknowledged by plant management and was considered as normal operation and was never fully investigated. Cylinder movement was reportedly observed as early as fifteen months prior to the accident.

The cylinder flange mounting bolts holding the cylinders in place on the A-Press frame, while not visibly loose, were found to be insufficiently torqued following the accident. Some bolts could be removed by hand and all had torque values well below the industry standard for the type and size of bolts. The bolts had not been re-torqued prior to the accident; however, visual examinations were reportedly conducted.

Summary of factors that led to cylinder failure

The failure of these cylinders was caused by a confluence of factors. The cylinder design as provided by the manufacturer did not account for all forces imposed upon the cylinders while in operation. The cylinders on the A-Press were not manufactured as designed and when subjected to higher than recommended hydraulic pressures, and head frame flex, created an environment where stress concentrations developed into cracks. These cracks (fatigue damage) propagated over time and effectively reduced the cross sectional area of the cylinder walls required to withstand forces exerted during normal operation. Extensive cracking and fatigue damage documented during a Non-Destructive Test (NDT) inspection of the B-Press showed that significant fatigue damage can occur at hydraulic operating pressures as recommended by the manufacturer. The excessive hydraulic pressures experienced by the A-Press exacerbated the failure process. Early warning signs of fatigue failure (cylinder movement) continued undiagnosed for several months. These factors combined with intermittent function of the hydraulic upper limit switch significantly contributed to a reduced cylinder service life, resulting in the catastrophic failure of the A-Press during operation, culminating in the death of a miner.

The mine operator conducted required examinations of both presses, examining press components for defects when problems were reported. However, the mine operator failed to fully investigate the root causes of the problems encountered on the presses. In an effort to maintain availability of the machine, it was evident that the mine operator made attempts at diagnosing the recurring issues, even calling upon the manufacturer's representative for assistance. For instance, the hydraulic pressure gauge/switch was adjusted by multiple individuals on multiple occasions, and as a result system hydraulic pressure was effectively reduced only when the gauge/switch worked properly. This manipulation of the gauge/switch was performed in an effort to stop the hydraulic pump motor. What the operator failed to realize was that the gauge/switch was malfunctioning (or functioning intermittently). The mine operator made attempts to diagnose press malfunctions but did not consider all options. As a result, an intermittently malfunctioning gauge/switch was not considered. Because of this, the mine operator did not consider the implications of excessive hydraulic pressures on the filter press. As such, many of the root causes continued undiagnosed and unfortunately unresolved.

Additional Hydraulic System Notes

The filter press system is unique in that hydraulic pressure in the system is generated by sources other than the hydraulic pump. A similar Jing Jin filter press at a nearby coal preparation plant was observed for reference purposes. After the hydraulic cylinders close the press, first slurry then air, is pumped into the system under pressure, creating a force which pushes back against the hydraulic cylinders, raising pressure in the hydraulic cylinders by up to 1,200 psi. This force is in addition to pressure previously generated by the hydraulic pump which is trapped in the cylinders. The hydraulic system is designed such that when the directional control valve is closed (cylinders fully extended); the hydraulic cylinders are isolated from the main system relief valve. This prevents the system relief valve from relieving additional hydraulic pressure induced by slurry and air pressure. In a typical hydraulic system, the relief valve is placed near the hydraulic pump to provide a safe outlet for potentially hazardous pump generated pressures. Since additional hydraulic pressure is generated as the press squeezes, an additional relief valve would provide relief for the hydraulic pressure generated by inducing pressurized slurry and air into the press. As designed, this circuit was not provided with a fail-safe system (or additional relief) to eliminate potentially hazardous pressures developed elsewhere in the system.

It should be noted that the hydraulic systems on both presses were not equipped with oil filtration and or separation equipment as recommended by the manufacturer. The manufacturer also recommends that the hydraulic fluid in both the reservoir and cylinders be replaced after the first week of operation, then after the first month and every six months thereafter. The hydraulic oil in use on both presses had been replaced once. The lack of oil filtration and oil replacement would adversely affect the performance of hydraulic components such as the combination pressure gauge/switch.

Structural Examination

A structural inspection of the supporting structure for the A-Press was conducted on March 6-7, 2013, by Terence M. Taylor, Senior Civil Engineer of MSHA's Mine Waste and Geotechnical Division. His inspection concluded that the concrete piers which provide support for the A-Press were damaged as a result of the lateral force associated with the rupture and release of the two large hydraulic cylinders. Therefore, it is not believed that failures in the foundation triggered the accident. Additionally, the inspection noted that the damage sustained by the concrete piers was generally superficial and they could be repaired and reused.

Computer Examination

An examination of the Allen-Bradley CompactLogix L32E Programmable Logic Controllers (PLC) programming associated with both presses was conducted to determine if programming modifications contributed to the failure of the A-Press.

Additionally, the operation of magnetic limit switches for each press was tested and an examination of software associated with the HMI computer was conducted.

The following lists the findings of these examinations, incorporated with statements from witnesses:

1. There were no substantive differences between the A-Press PLC program and the program found open on the victim's laptop.

2. Both the A-Press and the B-Press PLCs indicated that the Input/Output Force program feature, which is used to override ladder logic, was enabled. Although the feature was enabled, no input/output force commands were used in the programs.

3. Examination of the A-Press PLC AUTO_SUB subroutine indicated that if the system registered high hydraulic pressure before the press had closed completely, the slurry pump could start out of sequence. It was reported that on the day of the accident, the A-Press began feeding slurry while still in the process of closing. It should be noted that a failure of the upper limit switch in the guage/switch would send a signal to the PLC that high hydraulic pressure had been reached and thus allow the slurry pump to start. This condition, experienced by the day shift press operator on the day of the accident, further indicates a failure of the upper limit portion of the combination hydraulic gauge/switch. Starting of the slurry pump was based solely on a reading from the upper limit switch contacts in the guage/switch with no means of checking if that reading occurred at an appropriate step in the cycle. This means that if the

upper limit contacts failed to operate, the slurry pump would start before the press was closed.

4. All magnetic limit sensors tested on the A-Press and the B-Press indicated a change in state of the corresponding PLC input. The limit sensors functioned properly when tested.

The HMI was equipped with TightVNC remote access software. Press operators stated that occasionally during operation, the pointer on the HMI computer screen appeared to move on its own as if someone was remotely connected to the computer, often to examine historical trend data. Other statements indicated the remote access password was widely known within the company. The TightVNC software was configured to allow a remote user full control of the HMI computer, thereby allowing them full control of both filter press units. Examination of the Tight VNC software on the HMI computer indicated the logging feature was turned off, so there was no record of when or if someone connected to the computer remotely.

There were no defects found in the computer and electronic subsystems of the Jing Jin 2000 X 2000 X 40 filter press that contributed to the accident.

Examinations

Records for both on-shift and electrical examinations were reviewed for up to one year prior to the accident date. Examinations were conducted by the mine operator and no hazardous conditions were noted with respect to the press building or presses.

Training

Training records were evaluated for all employees associated with the preparation plant and filter press building on the day of the accident. No training deficiencies were found. The victims involved in this accident were performing specialized tasks and therefore did not require task training with respect to the normal operation of the membrane filter presses.

Agents of the mine operator received task training from the manufacturer's representatives upon start-up of both presses. This training related to general operation of the presses. The agents in turn provided the task training to the individual press operators (employees). The mine operator initially sought the advice and services of the manufacturer's representative when press problems were encountered, however eventually the operator began performing maintenance and adjustments without guidance from the manufacturer's representative.

ROOT CAUSE ANALYSIS

An analysis was conducted to identify the most basic causes of the accident that were correctable through reasonable management controls. During the analysis, root causes were identified that, if eliminated, would have either prevented the accident or mitigated its consequences.

Listed below are causal factors identified during the analysis and their corresponding corrective actions implemented to prevent a recurrence of the accident:

1. *Root Cause:* The mine operator had no policies or procedures in place for general maintenance of the presses and for investigation and correction of reported abnormalities with the hydraulic components associated with the presses. The mine operator failed to fully investigate the root causes of the problems encountered on the presses.

   Corrective Action: The mine operator has implemented policies and procedures for general maintenance and periodic inspection of the presses. Cylinder mounting bolts will be checked for movement weekly. Weekly inspections of the head frame will be performed by a qualified person to visually inspect for cracking and paint deflection. Ultrasound or magna-flux testing of this area will take place at least quarterly. A structural exam of the plate and frame press and building will be conducted within the first six months of operation after restarting the system and again within the next six months after that. If no significant issues are found by these exams, the interval will be extended to twelve months. This examination will be conducted by a qualified professional engineer. If any defects are found they will be promptly corrected. All examinations will be recorded, and a record made even if no defects are found. These records will be kept at a central location for the life of the machine. The mine operator has also retrained all persons associated with the operation of the presses with respect to proper operation and troubleshooting procedures.

2. *Root Cause:* The hydraulic cylinders, provided by the manufacturer, were not constructed according to the design and materials criteria provided by the manufacturer.

   Corrective Action: The original hydraulic cylinders were removed from service. The replacement cylinders were placed on a schedule of regular examination and non-destructive testing. Ultrasonic testing of the replacement cylinders will be performed after the first month of operation. If no defects are found, testing will repeat every three months thereafter for the first year. If no defects are found, testing will continue on a six month basis for the next two tests. If no defects are found, testing will be performed annually. Records of these examinations will be maintained by the mine operator.

3. *Root Cause:* The combination hydraulic gauge and pressure switch as originally installed was not provided with a failsafe or backup system to ensure the hydraulic pump would stop.

   Corrective Action: Dual hydraulic pressure transducers were installed in lieu of the original combination gauge and switch. These dual transducers are connected to the PLC system and enable it to stop the hydraulic system once desired pressure is reached. Also, the readings from the transducers are visible on the PLC screen so that the operator can see them. These measurements are saved and trends are recorded in the PLC system. These dual transducers provide a failsafe or backup to ensure that the hydraulic pump will stop at the desired pressure. The transducers will be recalibrated or replaced on an annual basis. Gauges have been installed as a visual check for transducer accuracy and will be viewed by the press operators while operating the presses.

4. *Root Cause:* The presses were installed in such manner that allowed persons to travel near pressurized hydraulic components.

   Corrective Action: The mine operator implemented a time and space barrier in order to reduce exposure to pressurized components. Area guards were placed across the walkway where the accident occurred. These guards are secured by lock and the key is retained by plant management. Hydraulic gauges were moved to a safe location where they could be observed without exposure to press componentry. Warning lights were also installed to warn press operators when the feed cycle, or pressurizing of the press, was beginning. This indicates that press operators are to move to another location while slurry is injected into the presses to reduce exposure to slurry blow outs. Plexiglass was also provided on the sides of both presses in an effort to prevent exposure to slurry spray while traveling alongside the presses.

5. *Root Cause:* The hydraulic pressure relief valve was readjusted to 4,800 psi by the mine operator contributing to the ultimate failure of the hydraulic cylinders.

   Corrective Action: The original relief valve as supplied by the manufacturer was set at 3,190 psi. The hydraulic system operating pressure, as recommended by the manufacturer is 2,312 psi. The main system relief valve, at the pump manifold is now set at 2,500 psi. Additional tamper resistant hydraulic relief valves set to 3,600 psi were installed near the cylinders on both presses. The mine operator will perform a function test of these valves every six months. Any defective component will be replaced immediately.

CONCLUSION

Several factors contributed to this accident. The design of the hydraulic system was insufficient for its intended use. The hydraulic cylinders were not manufactured according to their design and were constructed using substandard materials. The combination hydraulic pressure gauge/switch functioned intermittently, and as a result allowed the hydraulic pump to supply excess hydraulic pressure. The A-Press hydraulic system main relief valve was adjusted to exceed the manufacturer's recommended operating pressures. The mine operator failed to maintain the presses in safe operating condition, and did not have any policies or procedures in place to investigate and remedy reported mechanical and hydraulic issues with the press. As a result of these contributing factors, the cylinders developed fatigue cracks which compromised their integrity and contributed to their ultimate failure, and the death of a miner.

Approved By:

David S Mandeville — 3/18/14

David S. Mandeville
District Manager

Date

ENFORCEMENT ACTIONS

1. A 103(j) Order, No. 8152248, was issued on February 6, 2013, to ensure the safety of persons at the mine until all areas and equipment were deemed safe.

2. A 104(a) Citation, No. 7189373, was issued for a violation of 30 CFR 77.404(a), stating the mine operator failed to maintain the Jing Jin membrane filter press "A-Press" in safe operating condition. Upon completion of a fatal accident investigation involving this machine it was found that the machine had been repeatedly subjected to hydraulic pressures in excess of design parameters primarily due to an intermittently functioning hydraulic pressure switch and an improperly adjusted main system relief valve. The main system relief valve was adjusted from 3,190 to 4,800 psi. These conditions contributed to fatigue damage which weakened the cylinder walls which resulted in their sudden and catastrophic failure. This is a contributing factor in a fatal accident which occurred at this mine on February 6, 2013 at approximately 4:00 p.m. Mobile and stationary machinery and equipment shall be maintained in safe operating condition and machinery or equipment in unsafe condition shall be removed from service immediately.

APPENDIX A

Persons Furnishing Information and/or Participating In the Investigation

Five Mile Preparation Plant and Refuse Facility

David A. Kimbrell	Plant Superintendent
Roy L. Gibson	Day Shift Plant Foreman
Kevin D. Clay	Electrician
Greg D. Morris	Dayshift Press Operator
Jimmie A. Tyler	Dayshift Press Operator
Jeffrey "Ted" Smith	Dayshift Press Operator
Thomas L. Hull	Night Shift Press Operator
Justin W. Howell	Plant Electrician
Travis Shamblin	Plant Technician
Freddie Long	Night Shift Electrician

Midland Trail Energy, LLC

Greg Dotson	General Manager
Aaron Price	Manager of Safety
Robert Phalen	Property Manager
Dwight Given	Maintenance Manager

Patriot Coal Corporation

Frank Foster	Director of Compliance
Roger Flemming	Senior Manager – Surface Equipment
Hulin Cook, Jr.	Senior Manager - Power and Automation
Joe White	Preparation Plant Engineer
Roger Graley	Director of Preparation Plants
Noah Toney	Electrical Controls Specialist

Tons Per Hour, Inc.

Michael Parker, Jr.	Owner
Vladimir Pikalov	Engineer
Sergio Arrieta	Engineer

APPENDIX A (continued)

Mine Safety and Health Administration

David Morris .... Staff Assistant
Joseph Mackowiak .... Assistant District Manager
Vince Nicolau .... Coal Mine Safety and Health Inspector
Jonathan A. Hall .... Mechanical Engineer
Eugene Hennen .... Mechanical Engineer
Patrick E. Retzer. .... Electrical Engineer
Matthew D. Heightland .... Electrical Engineer
Terence M. Taylor, P.E. .... Senior Civil Engineer
Harold Clay .... IT Specialist
Byron Tucker .... Coal Mine Inspector
Michael Boggs .... Surface Coal Mine Inspector

West Virginia Office of Miners' Health Safety and Training

William A. Tucker .... Administrator
McKennis Browning .... Inspector at Large
Garry Wolfe .... Surface Inspector
John Cruse .... Technical Analyst
Monte Heib .... Chief Engineer
Jack Rife .... Assistant Attorney General
Eddie Blake .... Instructor
Kendall Smith .... Electrical Specialist

Persons Interviewed

Interviews conducted on February 13, 2013

Kevin D. Clay .... Electrician
Greg D. Morris .... Dayshift Press Operator
Jimmie A. Tyler. .... Dayshift Press Operator
Jeffrey "Ted" Smith .... Dayshift Press Operator
Thomas L. Hull. .... Night Shift Press Operator
Justin W. Howell .... Plant Electrician
Edmond "Dwight" Given .... Maintenance Manager
David A. Kimbrell .... Plant Superintendent
Roy L. Gibson .... Day Shift Plant Foreman
Travis Shamblin .... Plant Technician
Robert L. Phalen .... Property Manager
Freddie Long .... Night Shift Electrician

APPENDIX A (continued)

Interviews conducted on February 14, 2013

Joseph White.. Preparation Plant Engineer

Interviews conducted on February 25, 2013

Roger D. Graley.. Director of Preparation Plants
Hulin Cook, Jr. .... Senior Manager – Power & Automation
Noah B. Toney.. Electrical Controls Specialist

APPENDIX B

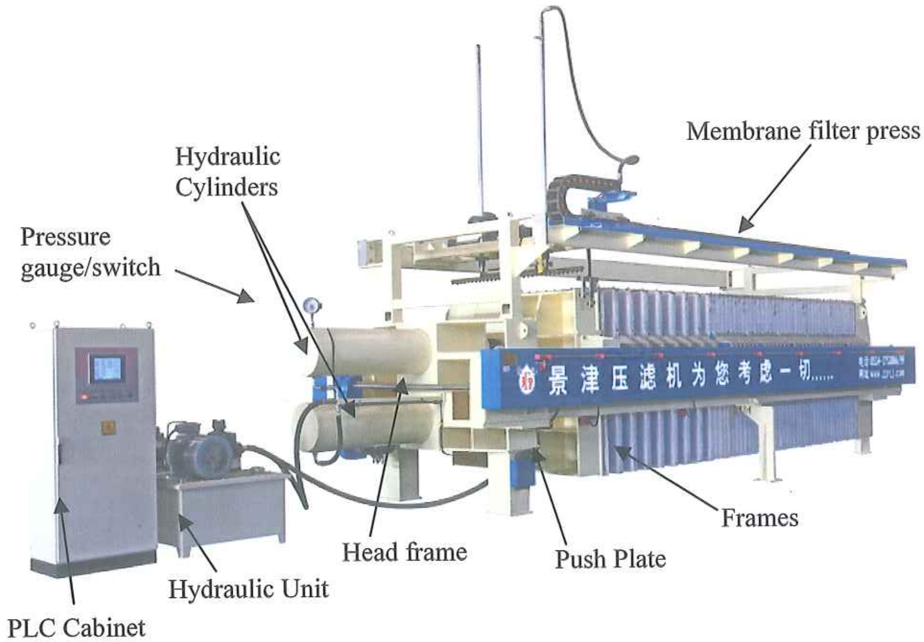
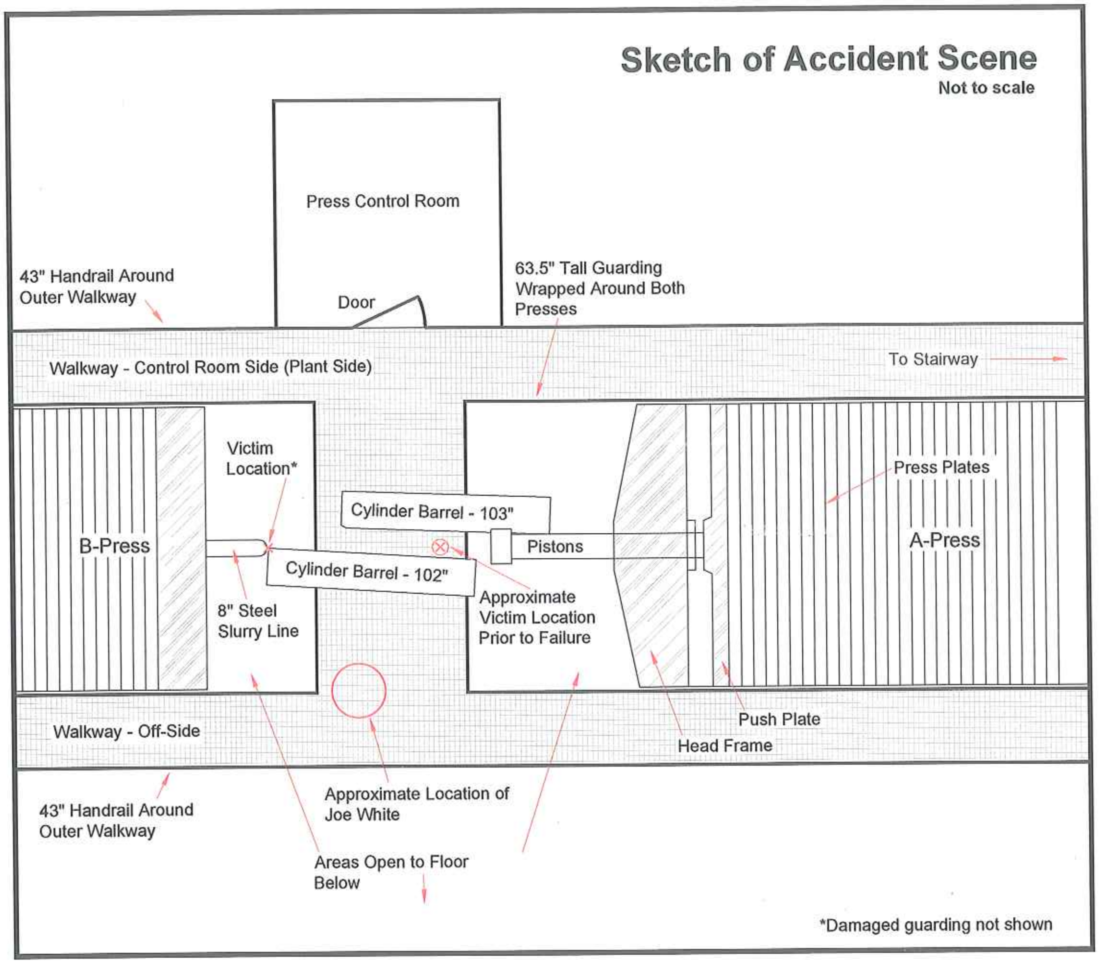


Photo of Jing Jin Membrane Filter Press from Jing Jin Website – Labeled for component identification

Aerial Image – Labeled to show relationship and orientation of structures.

APPENDIX C



Sketch of Accident Scene
Not to scale
Press Control Room
43" Handrail Around Outer Walkway
Door
63.5" Tall Guarding Wrapped Around Both Presses
Walkway - Control Room Side (Plant Side)
To Stairway
Victim Location*
Press Plates
Cylinder Barrel - 103"
B-Press
Pistons
A-Press
Cylinder Barrel - 102"
8" Steel Slurry Line
Approximate Victim Location Prior to Failure
Walkway - Off-Side
Push Plate
Head Frame
43" Handrail Around Outer Walkway
Approximate Location of Joe White
Areas Open to Floor Below
*Damaged guarding not shown

APPENDIX D
Hydraulic Pressure Gauge/Switch

This is a description of the hydraulic pressure gauge/switch combination unit used on the filter presses at the Five Mile Preparation Plant & Refuse Impoundment. The units from both presses were tested at W.C. Hydraulics following the accident. Both units are identical. Since the unit from the A-Press was damaged in the accident, the following pictures show the unit from the B-Press.

This hydraulic pressure gauge/switch combination unit provides mechanical control of hydraulic pressure in the filter press. If it malfunctions, the hydraulic pressure within the press cylinders is affected. The filter presses must maintain hydraulic pressure to complete the pressing operation. If hydraulic pressure is too high, unnecessary force is placed on the structure of the press and additional pressure resides within the hydraulic system components. If hydraulic pressure is too low, the press does not seal tightly and leaks or blowouts of slurry or air may occur.

This unit monitors hydraulic pressure and opens or closes electrical contacts based on the monitored hydraulic pressure and the settings of two adjustable pressure setting arms. These electrical contacts form two switches, one each for low pressure and high pressure. The electrical contacts are used to turn on and off the electric motor that turns the hydraulic pump that in turn provides hydraulic pressure to the hydraulic system.

The electrical output of the switches falls into three zones based on the pressure measured by the gauge portion of the gauge/switch combination unit. The first zone (low pressure zone) is defined by a pressure reading below the setting of the lower pressure setting arm. In this zone, the low pressure switch is open and the high pressure switch is closed. In the middle zone, defined by a pressure reading between the settings of the lower pressure setting arm and the upper pressure setting arm, the low pressure switch is closed and the high pressure switch is also closed. In the upper zone (high pressure zone), defined by a pressure setting above the upper pressure setting arm, the low pressure switch is closed and the high pressure switch is open. When the press is closed during a normal cycle, this unit helps maintain system hydraulic pressure within the middle zone. The three zones are shown in Illustration 1.

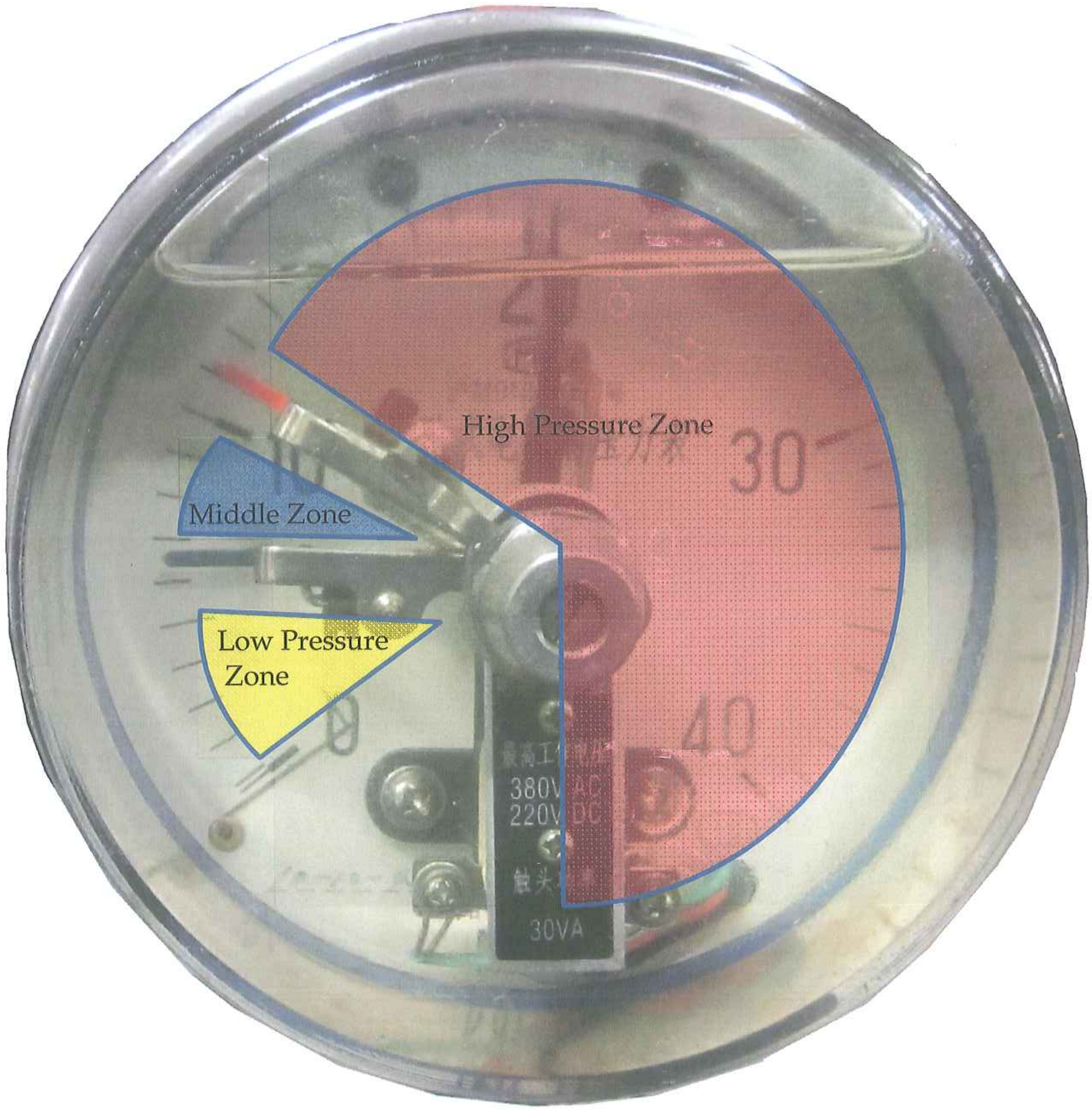


Illustration 1: Hydraulic Gauge/Switch Combination Unit showing switch output zones.

Each switch closes when a spring loaded arm presses against its respective pressure setting arm. Each switch opens when the spring loaded arm is held away from its respective pressure setting arm by the pressure gauge needle. Illustration 2 shows the high pressure setting spring loaded arm held away from the high pressure setting arm by the pressure gauge needle.

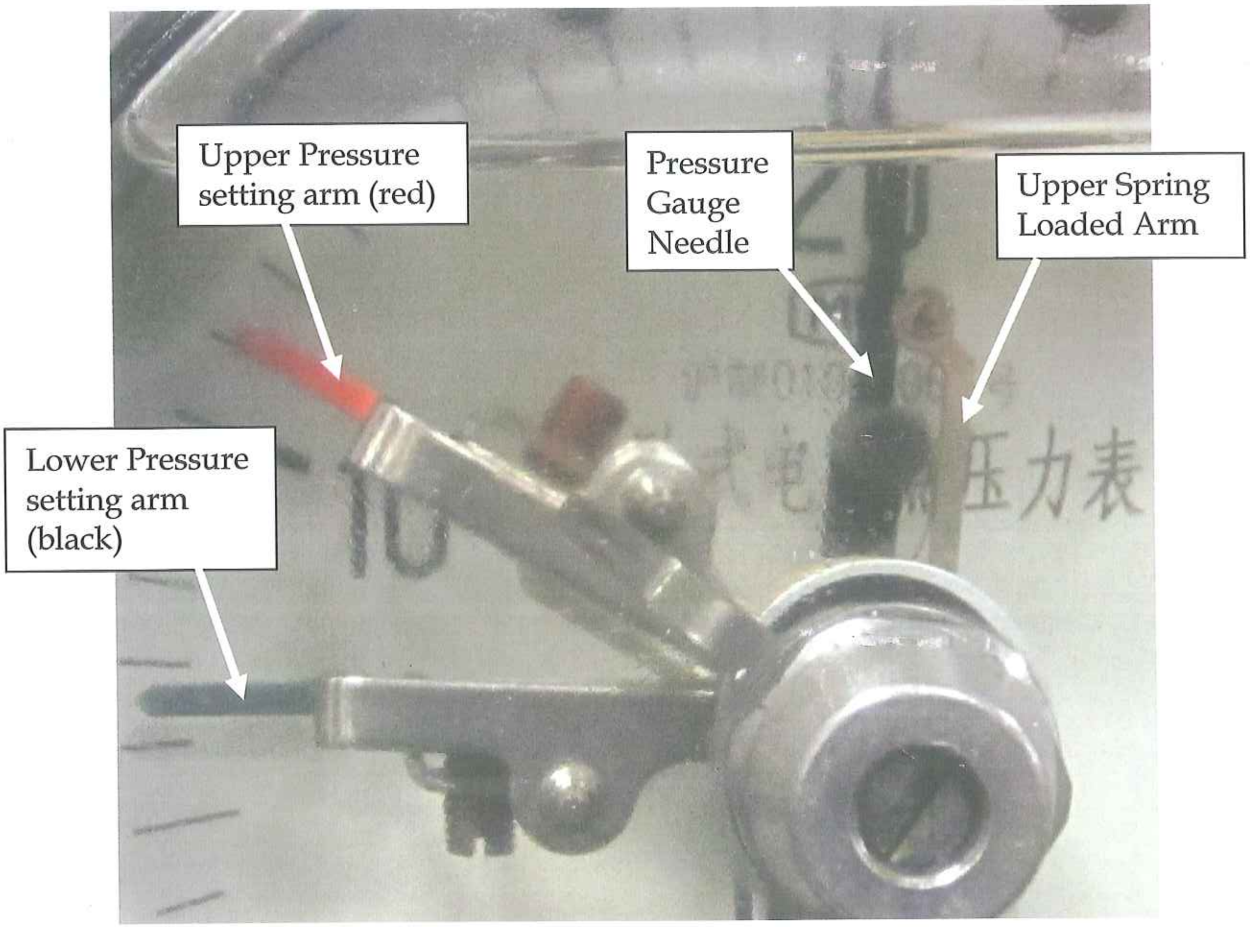


Illustration 2: Hydraulic Gauge/Switch Combination Unit showing a pressure reading in the high pressure zone. Note that a protrusion on the pressure gauge needle holds the upper spring loaded arm away from the upper pressure setting arm, opening the upper pressure switch. The lower pressure switch is closed and the lower spring loaded arm is not visible behind the lower pressure setting arm.

APPENDIX E
Victim Information

Accident Investigation Data - Victim Information

Event Number: | 6 | 2 | 9 | 7 | 5 | 8 | 0 |

U.S. Department of Labor
Mine Safety and Health Administration

Victim Information: 1

1. Name of Injured/Ill Employee: *Brandon E. Townsend* | 2. Sex: *M* | 3. Victim's Age: *34* | 4. Degree of Injury: *01 Fatal*

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *02/06/2013* b.Time: *16:28*

6. Date and Time Started: a. Date: *02/06/2013* b.Time: *6:00*

7. Regular Job Title: *102 Electrician, Automation Technician*

8. Work Activity when Injured: *039 Troubleshooting membrane filter press*

9. Was this work activity part of regular job? Yes | X | No | |

10. Experience:

	Years	Weeks	Days
a. This Work Activity:	1	12	0
b. Regular Job Title:	1	12	0
c. This Mine:	0	0	1
d. Total Mining:	9	16	0

11. What Directly Inflicted Injury or Illness? *068 Barrel end of hydraulic jack*

12. Nature of Injury or Illness: *370 Fatally struck by guarding/cylinder*

13. Training Deficiencies: Hazard: | | New/Newly-Employed Experienced Miner: | | Annual: | | Task: | |

14. Company of Employment: (If different from production operator) *Patriot Coal*

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment: Not Applicable: | | First-Aid: | X | CPR: | | EMT: | X | Medical Professional: | | None: | |

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

Victim Information:

1. Name of Injured/Ill Employee: | 2. Sex | 3. Victim's Age | 4. Degree of Injury:

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:

6. Date and Time Started:

7. Regular Job Title:

8. Work Activity when Injured:

9. Was this work activity part of regular job? Yes | | No | |

10. Experience: a. This Work Activity: Years Weeks Days b. Regular Job Title: Years Weeks Days c: This Mine: Years Week Days d. Total Mining: Years Weeks Days

11. What Directly Inflicted Injury or Illness?

12. Nature of Injury or Illness:

13. Training Deficiencies: Hazard: | | New/Newly-Employed Experienced Miner: | | Annual: | | Task: | |

14. Company of Employment: (If different from production operator)

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment: Not Applicable: | | First-Aid: | | CPR: | | EMT: | | Medical Professional: | | None: | |

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim:

Victim Information:

1. Name of Injured/Ill Employee: | 2. Sex | 3. Victim's Age | 4. Degree of Injury:

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:

6. Date and Time Started:

7. Regular Job Title:

8. Work Activity when Injured:

9. Was this work activity part of regular job? Yes | | No | |

10. Experience: a. This Work Activity: Years Weeks Days b. Regular Job Title: Years Weeks Days c: This Mine: Years Week Days d. Total Mining: Years Weeks Days

11. What Directly Inflicted Injury or Illness?

12. Nature of Injury or Illness:

13. Training Deficiencies: Hazard: | | New/Newly-Employed Experienced Miner: | | Annual: | | Task: | |

14. Company of Employment: (If different from production operator)

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment: Not Applicable: | | First-Aid: | | CPR: | | EMT: | | Medical Professional: | | None: | |

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim:

MSHA Form 7000-50b, Mar 2008 | Printed 01/30/2014 1:15:04 PM