APPENDIX U-3

EXECUTIVE SUMMARY OF INVESTIGATION OF ELECTROHYDRAULIC SHIELD CONTROL COMPONENTS

U.S. Department of Labor

Mine Safety and Health Administration
Approval and Certification Center
765 Technology Drive
Triadelphia, West Virginia 26059

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MEMORANDUM FOR NORMAN G. PAGE
Accident Investigation Team Leader

FROM: JOHN P. FAINI
Chief, Approval and Certification Center

SUBJECT: Executive Summary of Investigation of Electrohydraulic Shield Control Components Recovered from Performance Coal Company's Upper Big Branch – South Mine

The Approval and Certification Center (A&CC), as requested by Upper Big Branch Mine Accident Investigation Team Leader, Norman Page, conducted a laboratory investigation associated with respect to the electrohydraulic shield control components recovered from a fatal mine explosion at the Upper Big Branch Mine-South on April 5, 2010. The investigation focused on the area for the source of the explosion. The Accident Investigation Team determined this "zone of concern" to be from shield number 160 to the tailgate of the longwall.

The components received were:

One (1) Joy Mining Machinery Master Supply Unit (MSU) recovered from the longwall headgate area.

- Exhibit No. PE-0490, Type 375186-00-30, MSHA IA-408-10, P/N 06-01357, Serial No. JMM003.

One (1) KH Controls, Inc. MSU Power Supply recovered from an explosion proof enclosure at the longwall headgate area.

- Exhibit No. PE-0248-c*, Model ISS1-13.0-6.8-AL1 Power Supply, MSHA IA-13827-0, Serial Number 697.

Ten (10) Joy Mining Machinery MS 40 Chock Interface Units (CIU), Part No. 06-01383, IA-408-9, recovered from the longwall face.

1. Exhibit No. PE-0257, CIU from shield number 62, Serial No. JMM097.
2. Exhibit No. PE-0259, CIU from shield number 64, Serial No. R81M.
3. Exhibit No. PE-0335-a*, CIU from shield number 169, Serial No. JMM 168A.
4. Exhibit No. PE-0335-b*, CIU from shield number 170, Serial No. B867.

5. Exhibit No. PE-0334-a*, CIU from shield number 171, Serial No. E095.
6. Exhibit No. PE-0311-a*, CIU from shield number 172, Serial No. 07/E805.
7. Exhibit No. PE-0334-b*, CIU from shield number 173, Serial No. JMM 171.
8. Exhibit No. PE-0311-b*, CIU from shield number 174, Serial No. 164.
9. Exhibit No. PE-0273-b*, CIU from shield number 175, Serial No. E097.
10. Exhibit No. PE-0273-a*, CIU from shield number 176, Serial No. JMM 060A.

Eight (8) Shield Control Solenoid Valves recovered from the longwall face.

1. Exhibit No. PE-0255-a*, solenoid valve recovered from shield 145 with side label indicating "Joy Mining Machinery HPS04751" and no legible information on bottom nameplate.
2. Exhibit No. PE-0255-b*, solenoid valve recovered from shield 145 with side label indicating "United Mining Equipment 23739" and no pertinent information on bottom nameplate.
3. Exhibit No. PE-0310-a*, solenoid valve recovered from shield 170 with no side label and no bottom nameplate.
4. Exhibit No. PE-0310-b*, solenoid valve from shield 170 with no side label and bottom nameplate indicating "Joy Mining Machinery Type 146420-01-30 66069897".
5. Exhibit No. PE-0310-c*, solenoid valve recovered from shield 170 with side label indicating "United Mining Equipment 14375" and no legible information on bottom nameplate.
6. Exhibit No. PE-0310-d*, solenoid valve recovered from shield 170 with no side label and partially legible information marked on bottom nameplate. The legible nameplate information matches labeling on PE-0310-b.
7. Exhibit No. PE-0310-e*, solenoid valve recovered from shield 170 with no side label and no pertinent information on bottom nameplate.
8. Exhibit No. PE-0310-f*, solenoid valve recovered from shield 170 with no side label and bottom nameplate indicating "Type 146420-01-30 66069897" with no manufacturer's name.

Nine (9) Miscellaneous Components recovered from the longwall face or the longwall tailgate area.

1. Exhibit No. PE-0284, CIU stainless steel cover plate.
2. Exhibit No. PE-0272, shield to shield cable marked 169-170.
3. Exhibit No. PE-0229, front panel circuit board from a CIU.
4. Exhibit No. PE-0283, main circuit board from a CIU.
5. Exhibit No. PE-0488, CIU enclosure containing no circuit boards, and no front cover.

6. Exhibit No. PE-0486-a*, CIU cast aluminum front cover with stainless steel cover plate, and main/front panel PCBs attached.
7. Exhibit No. PE-0486-b*, CIU cast aluminum front cover with missing approximately ¼ of top center area.
8. Exhibit No. PE-0486-c*, approximately ¼ of bottom center area of CIU cast aluminum front cover.
9. Exhibit No. PE-0486-d*, MS40, Part No. 06-01383, Serial No. 096 CIU nameplate.

Fourteen (14) Components recovered from a warehouse.

1. Exhibit No. PE-0326-a*, Joy/Marco Type sns/dmd/d8, P/N 07-00504 leg pressure transducer, Joy Part No. 08-01653, Serial No. 68342/2.
2. Exhibit No. PE-0326-b*, Joy P/N 08-01653, 800mm cable assembly. Joy indicated that this cable interconnects the MS40 CIU and the RS20 solenoid valve junction box. Since no RS20 junction boxes were provided, it is assumed that this cable was mistakenly submitted.
3. Exhibit No. PE-0326-c*, United Mining Equipment P/N 08-00968 RAM transducer cable assembly.
4. Exhibit No. PE-0326-d* is a P/N 66161558 solenoid valve junction box.
5. Exhibit No. PE-0326-e*, United Mining Equipment P/N 08-00675 leg transducer cable.
6. Exhibit No. PE-0326-f*, Joy/Marco Type sns/rs/j1150c RAM transducer and housing tube, Joy Part No. 06-01307, Serial No. 34355-94.
7. Exhibit No. PE-0346-a* is a solenoid valve labeled HPS01952.
8. Exhibit No. PE-0346-b* is a solenoid valve labeled HPS04932.
9. Exhibit No. PE-0346-c* is a solenoid valve labeled HPS02569.
10. Exhibit No. PE-0346-d* is a solenoid valve labeled HPS02087.
11. Exhibit No. PE-0346-e* is a solenoid valve labeled HPS01941.
12. Exhibit No. PE-0346-f* is a solenoid valve labeled HPS02569.
13. Exhibit No. PE-0346-g* is a P/N 08-00676 CIU-to-junction box cable.
14. Exhibit No. PE-0346-h* is a P/N 66161558 solenoid valve junction box.

*Note: Multiple pieces of evidence that arrived at the A&CC under one exhibit number (e.g. Exhibit No. PE-0248 consisted of two lighting system power supplies and one shield control system power supply) were expanded into new unique exhibit numbers containing a dash followed by a letter (e.g. Exhibit No. PE-0248-c).

The investigation began with a preliminary inspection of all the shield control components recovered from the longwall face and a warehouse. The preliminary

inspection included documenting visual observations, and photographing the as received condition of the components. The most significant observations were that there were signs of melting observed on some of the CIUs around the buzzer, infrared receiver lens, and switch plate membrane; and differences in the construction of the solenoid valves.

The next phase of the investigation included testing of some of the recovered components as well as experimental testing of non-evidence. Some of the detailed inspection that would not interfere with testing was conducted in conjunction with the testing phase. Tests of the system included spark ignition testing at the output of the power supply, spark ignition testing simulating various system inductances, power supply load capacitance spark ignition testing, and spark ignition testing simulating various solenoid valve configurations. No spark ignition test failures involving the recovered equipment were observed. CIU performance testing revealed that all except for one of the CIUs were functional to some degree. No specific faults of malfunctioning CIU circuits were identified during the performance testing. Experimental testing of non-evidence included determining the maximum current in which several wire strand sizes will remain below 150 °C (minimum ignition temperature of coal dust). Testing of the MSU revealed that all ten opto-isolators were capable of isolating a 20 Vdc power supply from input to output.

The next phase of the investigation included a detailed inspection of all the shield control components recovered from the longwall section and a warehouse. For the equipment recovered from the longwall section, this involved disassembling the equipment to address irregularities found during the preliminary inspection or testing; determining whether any of the components showed signs of electrical heating, arcing, or sparking; and determining if any of the units contained faults which could be an ignition hazard. After disassembling and inspecting the equipment recovered from the longwall section, no faults, signs of arcing or sparking, or signs of electrical heating were observed to be caused by the shield control components. For the equipment recovered from a warehouse, this involved determining interconnection of components and whether the junction boxes used during spark ignition testing contained any components that would affect the results of the test. Additional detailed inspection of cutting open cables to determine minimum strand size used to construct conductors and breaking away encapsulant of two solenoids to determine the diode type and configuration was also conducted.

The last phase of the investigation was comparing the recovered components to documentation on file at the A&CC. The encapsulated equipment (solenoid valves, sensors, and bottom half of the power supply) were not compared to the approval documentation. Discrepancies between the components and approval documentation were found, however, none of the discrepancies were considered to be factors in the accident.

It was concluded that:

1. The output of the power supply is not considered an ignition source of a methane-air atmosphere.

2. The inductive energy stored in the MSU-to-CIU, CIU-to-CIU, and CIU-to-sensor/solenoid valve cabling is not an ignition source of a methane-air atmosphere provided the unrecovered cables are similar to the cable measured at the Approval and Certification Center.

3. The inductive energy stored in twelve (12) solenoid valves is not an ignition source of a methane-air atmosphere provided the unrecovered solenoid valves are similar in construction to those tested. Twelve solenoid valves were chosen for the test since there were two shield operators on the longwall face at the time of the accident, and each shield has a total of six (6) solenoid valves.

4. Based on measurements and evaluation, other inductors used in the system such as relay coils within the MSU, MSU/CIU buzzer drive coils, or the dump valve are not considered an ignition source of a methane-air atmosphere since measurements confirmed that no faults existed that would connect the inductors in a manner capable of being an ignition hazard.

5. The only components identified in the recovered evidence capable of generating electrical energy were a battery within the MSU and piezo-electric crystals used to provide an audible warning for the CIUs and MSU. Based on the approval documentation, the battery does not have adequate energy when compared with published ignition curves to cause a spark ignition of a methane-air atmosphere. Based on measurements, inspection, and the original approval testing of the buzzers, the piezo-electric crystals are not considered an ignition source of a methane-air atmosphere provided the unrecovered CIUs are built according to the approval documentation.

6. The energy stored in the total system capacitance is not considered an ignition source of a methane-air atmosphere provided the unrecovered CIUs are built according to the approval documentation.

7. No signs of electrical heating, arcing, or sparking were observed within or caused by any of the CIUs or solenoid valves recovered from the "zone of concern" of the longwall face. The heat damage observed on the CIU buzzers and infrared receiver lenses was judged to be from an outside force. No faults that would affect the intrinsic safety of the components were found.

8. A thermal ignition caused by wire strands used to construct the individual conductors of the shield control system is not considered an ignition source of a methane-air atmosphere based on testing/evaluation of wire strands, and assuming the minimum measured resistance of the recovered CIU-to-CIU cable (Exhibit No. PE-0272).

9. Circuit board traces of the type used in the CIUs are not considered an ignition source of a methane-air atmosphere provided the unrecovered CIUs are built according to the approval documentation. The circuit board traces have adequate current carrying capacity to not be considered capable of smoldering a coal dust layer with up to 1.2 A of current available at the "zone of concern".

10. Although examples of permissibility discrepancies were identified that may render the components or system less safe than originally approved, none of the identified permissibility discrepancies are considered to be a contributing factor in the accident.