U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236

Mine Electrical Systems Division

April 4, 2007

MEMORANDUM FOR RICHARD A. GATES
District Manager
CMS&H District 11

THROUGH: M. TERRY HOCH
Chief, Pittsburgh Safety and Health Technology Center

FROM: WILLIAM J. HELFRICH
Chief, Mine Electrical Systems Division

SUBJECT: Sago Mine Pump Cable Test

Attached is a copy of the subject report which details the testing that was conducted on a section of a pump cable removed from the sealed are of the Sago Mine (ID #46-08791), located in Upshur County, West Virginia.

If you have any questions, please contact William Helfrich at (412) 386-6959 or email at Helfrich.william@dol.gov.

Attachment

cc: R. Phillips, CMS&H District 2

bcc: M. Skiles, TS w/attach
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R. Stoltz, VENT w/attach
W. Helfrich, MESD w/attach
D. Skorski, MESD w/attach
MESD Files w/attach

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UNITED STATES DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
PITTSBURGH SAFETY AND HEALTH TECHNOLOGY CENTER
MINE ELECTRICAL SYSTEMS DIVISION (MESD)

REPORT NO:	L-04022007-1
INVESTIGATION DATE:	January 31, 2007
LOCATION:	NIOSH Mine Electrical Laboratory Pittsburgh Research Center
INVESTIGATORS:	William J. Helfrich Chief, MESD
	Dean F. Skorski Supervisory Electrical Engineer, MESD
WITNESSES:	Robert L. Phillips Acting District Manager, CMS&H – District 2
	Monte Hieb WV Office of Miners' Health, Safety, & Training
	John Hall WV Office of Miners' Health, Safety, & Training
	William Hutchens Attorney – Jackson Kelly
SUBJECT:	Inspection and Testing of Sago Mine Pump Cable

INTRODUCTION

On December 4, 2006, the Mine Electrical Systems Division (MESD) was requested to obtain a section of a pump cable from the sealed area of the Sago Mine. Arrangements were made with Coal Mine Safety and Health (CMS&H) District 3 and the mine operator to retrieve the cable on December 7, 2006. MESD took possession of the cable on that day and has securely maintained the section of cable. A water bath testing of the cable, which provides information on the dielectric strength of the conductor insulation and jacket, was conducted on January 31, 2007.

CABLE TESTING PROCEDURES

The following cable tests used the test procedures in NEMA WC-70/ICEA S-95-658-1999, titled "Ethylene-Propylene-Rubber Insulated Wire and Cable – Nonshielded 0-2kV Cables," Section 6.10.1 - "Voltage Tests" as a guideline.

General

These tests consisted of voltage tests on a Tiger Brand Cable, AWG #6, 3-conductor, type G-GC, 2000 volt cable. Each conductor was tested separately, and a voltage was applied between individual conductors and the grounded water tank.

The multiple conductor cable was immersed in water for at least 12 hours and tested while still immersed.

Resistance Test

After the cable has been immersed in water for the determined time, a resistance test was made between each conductor and the tank frame, as well as between each of the conductors. A continuity measurement was also made on each conductor in the cable.

Alternating Current Voltage Test

This test was made with an alternating potential from a transformer of ample capacity, which was in no case less than 3 kilo-volt-amperes. The frequency of the test voltage was nominally between 49 and 61 hertz, and had a wave shape approximating a sine wave as closely as possible.

Single-phase voltage was applied separately across each of the four (4) insulated cable conductors and the two (2) ground conductors, and tank frame. The order was red, white, black, yellow (ground check), ground 1, and ground 2. The tank frame was grounded to the power system ground.

The rate of increase from initial applied voltage of zero (or previous test voltage) to each following applied voltage for the specified test voltage was approximately uniform and was not more than 100 percent in 10 seconds nor less than 100 percent in 60 seconds.

The duration of the alternating-current test voltage to the immersed cable was as follows for each conductor:

Voltage		Duration
100 volts	-	5 minutes
200 volts	-	5 minutes
300 volts	-	5 minutes
400 volts	-	5 minutes
500 volts	-	5 minutes
600 volts	-	5 minutes
700 volts	-	5 minutes
800 volts	-	5 minutes
900 volts	-	5 minutes
1000 volts	-	5 minutes
1200 volts	-	5 minutes
1400 volts	-	5 minutes
1600 volts	-	5 minutes
1800 volts	-	5 minutes
2000 volts	-	5 minutes (maximum rating of cable)

End of Test

Measurements were made of voltage and current flow in the ground path for each of the voltage levels. If a current of a least 100 milli-amperes was detected at any voltage level, the test was terminated, and NO additional testing was conducted on that conductor.

It was possible that a catastrophic failure of the conductors in the cable could occur during this testing. The power supply was provided with ground fault tripping, which was not adjustable and was approximately 5.4 amperes.

If a current of a least 100 milli-amperes was not detected through the 2000-volt test level, NO additional testing was conducted on that conductor individually as it had passed this part of the test.

Test Setup (see Figure 1 below)

Electrical testing was conducted in a metal tank, with each side and depth of approximately 3 feet. The tank was grounded to the power system ground and filled with tap water. The test cable was immersed in tank water, which was maintained at room temperature for at least 12 hours, and the water level was kept constant.

The length of the test cable was approximately 190 feet. The cable was rolled onto a fabricated reel to permit the cable to fit into the tank in its entirety. The outer jacket of the first 6 inches of each end of the cable was stripped away. The three-phase conductors, ground check wire, and two ground wires were isolated from each other on each end. Approximately 1 inch of conductor insulation was removed from each insulated conductor (one end only) to facilitate connection of test leads.

A 1-foot portion (minimum) of each end of the cable was kept above water as leakage insulation.

A diagram of the test setup can be found at the end of this document (Figure 1).

Test Procedures

Resistance Test (No Power/Conducted with a Fluke Model 87 VOM)

1. Visual observation of the test cable.
2. Measure continuity of each conductor in cable (see results in Table 1 below).
3. Connect test leads to cable and tank.
4. Measure resistance of each conductor in the cable.
   a. Each conductor to the grounded water tank (see results in Table 2 below).
   b. Each conductor to all the other conductors (see results in Table 3 below).

Table 1. - Continuity Measurements of Each Conductor

Red	White	Black	Ground Check	Ground 1	Ground 2
0.1 ohms	0.1 ohms	0.1 ohms	0.2 ohms	0.5 ohms	0.5 ohms

Table 2. - Resistance Measurements of Conductors in Cable (measurements recorded in meg-ohms)

Red	White	Black	Ground Check	Ground 1	Ground 2
1.351	6.4	1.304	1.889	1.014	1.014

Tests were conducted with one lead of ohm-meter connected to each conductor and the other lead connected to the metal tank.

Table 3. - Resistance Measurements between Conductors in Cable

	Red	White	Black	Ground Check	Ground 1	Ground 2
Red		3.45M	78K	0.945M	31.2K	31.8K
White			9.65M	12M	8.74M	8.8M
Black				0.968M	40K	40K
Ground Check					29.7K	30.5K
Ground 1						0.3K
Ground 2						

"M" designates Meg-ohms (millions)
"K" designates Kilo-ohms (thousands)

Alternating Current Test Procedures (results are shown in Table 4 below)

1. Visual observation of the test cable (no power).
2. Connect test leads to cable and tank in the order described earlier (red, white, black, ground check).
3. **Remove all observers from test area.**
4. Engage main power switch.
5. Switch power source on.
6. Increase voltage to 100 volts at predetermined rate.
7. Hold voltage constant for 5 minutes time.
8. If current flow was below 100 milli-amperes, increase voltage to 200 volts at predetermined rate.
9. Hold voltage constant for 5 minutes time.

10. If current flow was below 100 milli-amperes, increase voltage to 300 volts at predetermined rate.
11. Hold voltage constant for 5 minutes time.
12. If current flow was below 100 milli-amperes, continue increasing the voltage in 100-volt increments (or 200-volt increments, see table below) up to the 2000 volt limit.
    NOTE: If current flow exceeded 100 milli-amperes at any voltage level, testing was over for that conductor.
13. Decrease test voltage to zero.
14. Switch power source off. Keep key on person.
15. Bleed off any static charge on water tank with shorting stick. Hang shorting stick on tank.
16. Connect test lead to different conductor.
17. Remove shorting stick.
18. Repeat from Step 5.

Table 4. – Cable Testing Results (individual conductor to grounded tank frame)

	Current Level Through Conductors (milli-amperes)					
Voltage Level (volts)	**Red**	**White**	**Black**	**Ground Check**	**Ground 1**	**Ground 2**
100	5	3	6	7	24V/107mA	24V/206mA
200	12	3	14	17		
300	16	4	22	20		
400	18	4	32	28		
500	19	5	37	29		
600	21	5	41	35		
700	25[1]	6	43	35		
800	29[2]	6	43	34		
900	9[3]	7	42	33		
1000	9[4]	8	41	36		
1200	12[5]	9	78	41		
1400	11[6]	10	100	40		
1600	12[7]	12		43[10]		
1800	GFT	13		250[11]		
2000		14				

Notes:
1 - ammeter briefly read over 100 milli-amps 3 times during test
2 - ammeter briefly fluctuated over 100 milli-amps 2 to 3 times
3 - ammeter read over 2 amps twice during test
4 - ammeter read over 2 amps twice during test
5 - ammeter read over 100 milli-amps numerous times during test

6 - ammeter fluctuated number times over 500 milli-amps and once over 1 amp
7 - ammeter read over 4 amps twice during test
8 - initially, ammeter read over 100 milli-amps
9 - ammeter averaged over 100 milli-amps for duration of test
10 - ammeter fluctuated over 100 milli-amps several times during test
11 - ammeter averaged over 250 milli-amps at beginning of test
GFT - ground fault trip on power supply (current level at least 5.4 amps)

The white phase conductor passed the testing at the voltage rating of the cable (2000 volts). The investigators decided to test this cable further to determine the voltage level at which it would fail. The additional testing procedures followed the previous procedures with the exception of the duration at each voltage level. A 1-minute hold at each voltage level would be used to determine the level of voltage for the white conductor to meet the failure criteria. The following table illustrates the results of this additional testing (Table 5).

Table 5. - Cable Testing Results
(voltages above the 2000-volt rating of the cable under test)

Current level through white phase conductor (milli-amps)

Voltage Level (volts)	Red	White	Black	Ground Check	Ground 1	Ground 2
2500		18				
3000		21				
3500		24				
4000		27				
4500		30				
5000		36				
5500		GFT				

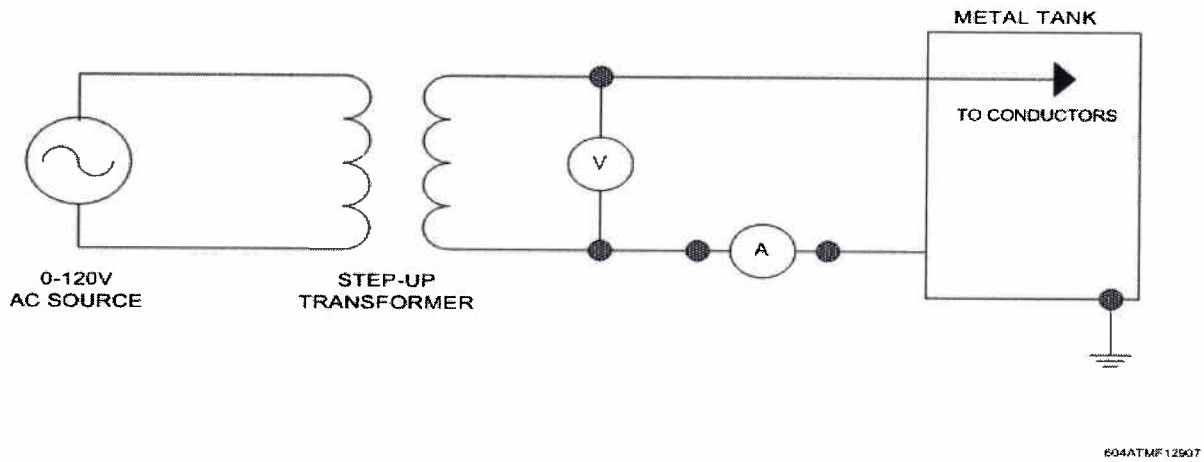

Figure 1. – Test Set-Up

VISUAL OBSERVATIONS

Following the removal of the cable from the water bath testing, the cable was allowed to dry. The cable was then removed from the cable reel and all damaged areas and splices were documented. The table below (Table 6) provides the locations of damaged areas and splices with respect to the coupler (cat head) end of the cable. The measured length of the cable was 192.5 feet.

Table 6. - Visual Observations of Pump Cable
(all measurements (in feet) are from coupler end of cable)

Damaged Sections (includes nicks, slices, cracks, etc.)		Spliced Sections (included permanent and temporary splices) T: Temporary P: Permanent	Taped Sections
11.5	27	87.3 P	17.7
37.7	46	132.8 P	33.5
65.9	87.1	146.7 T	
93.4	94.7	182.9 P	
96.9	99		
100.3	105.4		
108.1	108.4		
110.9	111.7		
112.1	114.9		
120.4	121		
128.1	131.3		
132.1	135.2		
138.7	139.5		
141.7	144.6		
150.7	162.4		
168.8	171.9		
174.3	180.3		
185.7	186.5		
186.9	187.8		

SUMMARY

The water bath testing of the pump cable revealed that the insulation on three of the four insulated conductors in the cable (red, black, and ground check) failed prior to the test voltage reaching the rated voltage of the cable (2000 volts). The white conductor reached a voltage of approximately 5,500 volts before a failure of the insulation occurred. The design of the cable did not provide insulation for the 2 ground conductors. As expected, they both failed at a very low voltage.
There were numerous locations on the cable jacket where significant damage was apparent. There were three permanent splices and one temporary splice in the section of cable tested. Based on the overall condition of this relatively short section of cable, the test results confirmed the anticipated failure of the insulation surrounding the conductors.