MAI-2007-08

UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
Metal and Nonmetal Mine Safety and Health

REPORT OF INVESTIGATION

Surface Metal Mine
(Iron Ore)

Fatal Machinery Accident
April 18, 2007

United Mine
United Taconite, LLC
Eveleth, St. Louis County, Minnesota
Mine I.D. No. 21-03403

Investigators

William T. Owen
Supervisory Mine Safety and Health Inspector

James A. Hines
Mine Safety and Health Inspector

Amy A. Lindgren
Mine Safety and Health Specialist

Ronald Medina
Mechanical Engineer, P.E.

Originating Office
Mine Safety and Health Administration
North Central District
515 West First Street, Room 333
Duluth, MN 55802-1302
Steven M. Richetta, District Manager

Post-Accident Position of Drill

OVERVIEW

Deane E. Driscoll, drill operator, age 50, was fatally injured on April 18, 2007. He was operating a drill positioned near the edge of a highwall bench when the drill tipped on its side. Driscoll was ejected from the operator's cab and over the edge of the highwall.

The accident occurred because management procedures and controls were inadequate and failed to ensure that persons could safely operate the drill. Procedures had not been established specifying the grades and slopes where the drill could be safely operated. Consequently, persons operating the drill were not adequately trained because this information had not been provided to them.

GENERAL INFORMATION

United Mine, an iron ore (taconite) mining operation, owned and operated by United Taconite LLC, was located in Eveleth, St. Louis County, Minnesota. The principal operating official was Todd D. Roth, vice president and general manager. The mine normally operated multiple shifts, 24 hours a day, 7 days a week. Total employment was 211 persons.

Iron ore was mined from multiple benches and drilled, blasted, and removed from a multiple bench quarry. The material was crushed and milled in a multiple step process. The finished pellets were transported by rail to docks and shipped to steel manufacturing companies.

The last regular inspection of this mine was completed on March 29, 2007.

DESCRIPTION OF ACCIDENT

On the day of the accident, Deane E. Driscoll (victim), reported for work at 7:00 a.m., his normal starting time. He was assigned a task to finish drilling a hole on the 1575 bench referred to as hole number 57. He completed that task, moved the drill, and completed drilling hole numbers 58 and 79.

About 10:45 a.m., Driscoll moved the drill to hole number 4 and began to raise and level the machine into position. As the drill was positioned, the drill end stabilizer jack on the non-cab side failed, resulting in the machine tipping down hill towards the highwall edge. The drill continued tipping and came to rest approximately 120 degrees from vertical as the mast contacted the lower bench. Driscoll was ejected from the operator's cab and landed on the lower bench approximately 35 feet below.

Richard M. Keil, fuel truck driver, was enroute to the drill and saw the mast tipping. He immediately radioed for help and began looking for Driscoll. Several miners heard the call for help and assisted in the search.

Emergency medical personnel arrived at the scene but Driscoll was non-responsive. He was pronounced dead at the scene by the St. Louis County Medical Examiner's deputy coroner. Death was attributed to massive trauma.

INVESTIGATION OF ACCIDENT

The Mine Safety and Health Administration (MSHA) was notified on April 18, 2007, at 11:16 a.m., by a telephone call from Michael A. Anderson, safety manager, to MSHA's emergency hotline. Steven M. Richetta, district manager, was contacted and an investigation began the same day. An order was issued pursuant to Section 103(k) of the Mine Act to ensure the safety of the miners.

MSHA's accident investigation team conducted a physical inspection of the accident site, interviewed employees, and reviewed conditions and work procedures relevant to the accident. MSHA conducted the investigation with the assistance of mine management, employees, the miners' representatives, and St. Louis County mine inspectors.

DISCUSSION

Location of the Accident

The accident occurred at the 1575 bench referred to as the Dairy Queen Hill area of the mine. The drill was located near the edge of a bench where the ground sloped downward to the northeast.

Drill

The drill involved in the accident was an Atlas Copco, Model Pit Viper 351E drill. It was crawler-mounted and had a rotary drilling unit designed for blast hole drilling. It was designed to drill $10_{5/8}$ to 16-inch diameter holes and had a single-pass depth capacity of 65 feet with a total depth capacity of 135 feet. Total machine weight was approximately 380,000 pounds.

Drilling functions were hydraulically powered and compressed air was used to clean the hole. A turbo-charged, 12 cylinder, 1500 HP, QSK45 Cummins engine powered a generator that in turn powered a 1400 HP electric motor. The electric motor was directly connected to a hydraulic pump drive gearbox on one end and an air compressor on the other end. The hydraulic driven drill feed system was capable of 125,000 pounds of bit loading and had a maximum drill pullback force of 75,000 pounds. A spur gear drive rotary head provided a maximum torque of 19,000 ft/lbs.

The drill used four leveling jacks to keep it level and stable while drilling. The drill tower was constructed of welded steel tubing. A carousel-type drill rod changer that held two pieces of 35-foot long drill rod was mounted to the tower. The tower was raised and lowered by two hydraulic cylinders.

All drilling functions were controlled from the operator's cab. The machine could be moved from inside the cab and also remotely from outside the cab by means of a pendant control attached to the drill.

The drill's Operating, Safety, and Maintenance Manual, provided precautions and guidelines regarding operating the drill while it was in a level position. Reference "2.2 – Safety Precautions and Guidelines" in the manual stated "Set up the drill on a level surface. If this is not available, the site should be adequately prepared prior to drill set up." Reference "3.1 – Specifications" in the manual stated "Set up the PV351E Blasthole drill on a level surface. If this is not available, prepare the site and the way to the site before set up and drilling with the PV351E."

Leveling Jack

The leveling jack controls were single axis spring return to center levers with a mechanical lock that consisted of a collar on the control handle. The collar on the handle had to be pulled upward to allow the control to move. The three jack control levers were located on the operator's left side. Each of the two leveling jacks on the drill end of the machine was controlled by a separate jack control lever. The third jack control lever controlled both leveling jacks on the non-drill end of the machine. The two non-drill end jacks shared a common hydraulic flow from a valve bank. Both leveling jacks received the same hydraulic pressure when the single jack control lever was moved to raise or lower them. The non-drill end leveling jacks were not visible from the operator's cab.

The machine was designed with an interlock that vented feed pressure for drilling unless the drill end leveling jacks were on the ground and were supporting the drill. This feature would not allow the operator to drill unless both drill end jacks were down. However, there was not a similar interlock for the non-drilling end leveling jacks. If one of the non-drill end jacks was fully extended and reached the end of its stroke, hydraulic pressure and flow would continue to be supplied to the other non-drill end jack and potentially allow the fully extended jack to be lifted off the ground.

Each hydraulic cylinder used to level the drill end of the machine was installed inside a cylindrical sleeve fastened to the frame of the machine. A cap plate was fastened to the top of each of the cylinder sleeves using four hex-head bolts. The bolts were Grade 8, size 1½ -6 x 5½, with a UNC 2A thread. A flange was welded to the top of each of the cylinder sleeves. Four holes through the flange lined up with four holes through the cap. The four bolts passed vertically through the holes and each bolt was held with a nut on the bottom side. A lock washer was installed under each nut. When the leveling jacks were used to support the weight of the machine, the rod end of the hydraulic cylinder inside each of the sleeves extended outward and pushed against the cap plate. This caused the body of the hydraulic cylinder to extend downward and push against the ground. The bottom of each cylinder was attached to a 45-inch diameter jack pad to distribute the load onto the ground.

The hydraulic cylinders that leveled the machine on the non-drill end were similar in design. A head frame was bolted on the top of the two lifting jack assemblies. Two tower rest support struts were attached between the head frame and the tower for tower stability.

Each of the four hydraulic cylinders was double-acting, had a single rod, and had through-the-rod-porting. An unloader valve in the spool valve assembly limited the maximum working pressure to 3,000 psi. The four hydraulic cylinders had a 10-inch diameter bore, a 7-inch diameter rod, and a 72-inch stroke.

Each hydraulic cylinder was provided with integral locking valves located inside the cylinder rod. The locking valves operated by blocking fluid flow leaving the hydraulic cylinders unless pilot pressure was directed to the locking valve by actuating the leveling jack control lever to raise or lower the jacks. Whenever the control levers were in the neutral position, the locking valve in each cylinder locked it in position by trapping a column of fluid in the hydraulic cylinders. This kept the leveling jacks locked in position despite any hose failures or leakage without depending on pump pressure. A second pilot line, internal to the locking valve, allowed for overpressure relief through the locking valve. The overpressure relief setting was set at 4,500 to 5,000 psi. Overcoming this overpressure relief valve setting would require a load induced pressure of approximately 356,000 to 395,000 pounds concentrated on one leveling jack.

A significant portion of the stroke for each leveling jack consisted of free travel from the fully raised position to the point where ground contact was made by the jack pad. With the machine on level ground, the drill end jacks had a free travel of 24 inches and the non-drill end jacks 27.5 inches. The effective working stroke was 48 inches for the drill end jacks and 44.5 inches for the non-drill end jacks. The drill end jacks were 23 feet, 1 inch apart and the non-drill end jacks were 9 feet, 3 inches apart. The front-to-back longitudinal distance between the drill end jacks and the non-drill end jacks was 36 feet, 7 inches. These dimensions were with respect to the jack centerlines.

Leveling Jack Positioning

At the time of the accident, the main tower of the drill was found fully elevated and locked in position, resting on the non-cab side, near the edge of a bench. The drill end of the machine had a surveyed side slope of 7.8 degrees with the non-cab side at the lower elevation. The ground at the opposite end of the machine (the non-drill end) had a side slope of 11.8 degrees with the non-cab side at the lower elevation.

The fore-and-aft slope elevations were 5.3 degrees on the cab side and 3.4 degrees on the non-cab side with the drill end of the machine at the higher elevation.

Investigators measured the extension of each leveling jack while the machine was resting on the non-cab side but could not determine if the amount of cylinder extension changed after the machine started to tip over. Both non-drill end leveling jacks were fully extended at 72 inches. The drill end, non-cab side leveling jack (the one that failed) was extended approximately 49 inches and the drill end cab side jack was extended 19 inches. Investigators determined the leveling jack at the non-drill, non-cab corner of the machine would not have been in contact with the ground based on the slope of the ground where the accident occurred and these cylinder extensions.

Leveling Jack Failure

Investigators determined that the first of the four bolts failed at the non-cab side, drill end, stabilizer jack during the midnight shift prior to the accident when the drill was in use at hole number 3. They found the failed bolt and a matching nut and lockwasher at

hole number 3 after the accident but could not determine when the failure occurred on the midnight shift. On this same shift, the drill was moved and hole numbers 11 and 35 were completed and hole number 57 was started.

The accident occurred on the next shift (day shift) when the leveling jack assembly at the drill end, non-cab side corner of the machine collapsed as a result of the failure of the remaining three bolts holding the cap plate to the jack assembly cylinder sleeve.

Based on examination of the four bolts, three showed signs of fatigue where a small initial crack continually became larger over time due to a fluctuating load. The remaining bolt failed in a more sudden fracture with no signs of fatigue. After the four bolts failed, the cap plate separated from the cylinder sleeve. When this occurred, the load bearing capacity of the leveling jack assembly was lost, allowing the leveling jack assembly to collapse. As a result, the machine tipped over onto the non-cab side of the machine.

The bolts were evaluated by an independent laboratory to determine hardness, chemistry, and microstructure. The summary section of this report (Appendix B) states, "The analysis of the bolts and bolt sections revealed the hardness was within specifications as provided by the manufacturer. The elemental composition of the material was also within specifications as noted in ASTM A354 and also matches closely to that of the manufacturer's testing data. Microstructural evaluation found that all four bolts had been quenched and tempered."

Weather Conditions

Weather conditions were clear, with slight winds and a temperature of 54 degrees Fahrenheit. Weather was not considered to be a factor in the accident.

Training and Experience

Deane E. Driscoll had 31 years and 10 weeks mining experience, all at this mine. He had approximately 3 years and 3 months experience as a drill operator and had received training in accordance with 30 CFR, Part 48.

ROOT CAUSE ANALYSIS

A root cause analysis was conducted and the following causal factor was identified:

Causal Factor: Management policies and procedures were inadequate and failed to ensure that persons could safely operate the drill on slopes and grades that were compatible with the drill's specifications and guidelines.

Corrective Action: Management should provide a stability/gradeability chart and train all persons operating the drill to ensure the machine is operated as specified by the manufacturer.

CONCLUSION

The accident occurred because management procedures and controls were inadequate and failed to ensure that persons could safely operate the drill. Procedures were not established regarding the grades and slopes where the drill could be safely operated. Consequently, persons operating the drill were not adequately trained.

ENFORCEMENT ACTIONS

Order No. 6193885 was issued on April 18, 2007, under the provisions of Section 103(k) of the Mine Act:

> A fatal accident occurred at this operation on April 18, 2007, when a miner was ejected from the cab of the drill he was operating when the stabilizer jack failed causing the machine to tip over. This order was issued to assure the safety of all persons at this operation.

The order was terminated on May 4, 2007. Conditions that contributed to the accident no longer exist.

Citation No. 6154850 was issued on November 20, 2007, under the provisions of Section 104(a) of the Mine Act for a violation of 30 CFR 56.14205:

> A drill operator was fatally injured at this mine on April 18, 2007 when the PV 351E drill he was operating tipped on its side. The drill was used beyond the manufacturer's design capacity in that: 1) the drill was utilized on a side slope angle that exceeded the maximum allowable limit and prevented all four leveling jacks from making contact with the ground to support the weight of the drill as designed 2) the mine operator failed to provide a stability/gradeability chart or references to the drill operator.

The citation was terminated on January 18, 2008. The drill was damaged in the accident and is inoperable.

Citation No. 6154851 was issued on November 20, 2007, under the provisions of Section 104(a) of the Mine Act for a violation of 30 CFR 48.27(a)(3):

> A drill operator was fatally injured at this mine on April 18, 2007 when the PV 351E drill he was operating tipped on its side. The drill was positioned on a sloped surface with a side slope angle that exceeded the manufacturer's maximum allowable limit. The task training instruction regarding safe operating procedures for this drill when it was new did not provide the drill operators with proper knowledge of the maximum grade and side slope limitations to ensure they could safely operate the drill.

The citation was terminated on January 18, 2008. The drill was damaged in the accident and is inoperable.

Approved By: Date:

Steven M. Richetta
District Manager
North Central District

APPENDIXES

APPENDIX A

Persons Participating in the Investigation

United Taconite LLC

Michael Smith	area manager of operations
E. Kimball Alvey	safety manager

United Steel Workers Union

Michael Maleska	president, Local 6860
Brian Lahti	safety coordinator, Local 6860
Larry Roberts	safety committee chairman, Local 6860
Gary Batula	safety committee, Local 6860
David Mlakar	health, safety and environmental advisor, District 11

St. Louis County

Stanley J Rojeski Jr.	assistant St. Louis County mine inspector
Terrance M. O'Neil	assistant St. Louis County mine inspector

Mine Safety and Health Administration

William T. Owen	supervisory mine safety and health inspector
James A. Hines	mine safety and health inspector
Amy A. Lindgren	mine safety and health specialist
Ronald Medina .	mechanical engineer, P.E.

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Touchstone Research Laboratory, Ltd.
The Millennium Centre
Triadelphia, WV 26059

EVALUATION OF GRADE 8 BOLT FAILURES

FROM A DRILL RIG

Report 6186

Submitted to: Mr. Ronald Medina
MSHA Approval and Certification Center
4 Industrial Park Drive
Triadelphia, WV 26059

Submitted by: Zach Witzgall
Touchstone Research Laboratory LTD.
RR1 Box 100B
Triadelphia, WV 26059

August 27, 2007

Signed _____ Date 9/6/07
Zach Witzgall

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INTRODUCTION

The purpose of this investigation was to evaluate four grade 8 bolts provided by Mine Safety and Health Administration to determine hardness, chemistry and microstructure. Bolts with identification 1, 3 and C all showed signs of fatigue by the presence of beachmarks on the fracture surface. The bolt that had a more sudden fracture with no signs of fatigue will be used for SEM analysis to find evidence of a ductile failure. The bolts were removed from the scene of a drilling rig accident and were delivered to Touchstone Research for analysis.

SUMMARY

The analysis of the bolts and bolt sections revealed the hardness was within specifications as provided by the manufacturer. The elemental composition of the material was also within specifications as noted in ASTM A354 and also matches closely to that of the manufacturers testing data. Microstructural evaluation found that all four bolts had been quenched and tempered. Dimples were found on the fracture surface which is a characteristic of a ductile failure.

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PROCEDURE AND RESULTS

The fracture surfaces of the bolts were photographed upon receipt (Figures 1 – 4). The fracture surface from a specimen, identified as 'X5', was removed for SEM analysis. Hardness testing was performed on all specimens using a standard Rockwell hardness machine. Elemental composition was performed using a Leco Combustion Infrared for carbon and sulfur and Inductively Coupled Plasma spectrometry (ICP) for phosphorus. Microstructure analysis required the specimens to be mounted in an epoxy, etched with 1% Nital solution and analyzed using a metallograph.

SEM Analysis

The fracture surface from the bolt with identification 'X5' was removed by bandsawing. The cut was made approximately one-quarter of an inch from and parallel to the fracture surface. This section was cleaned in an ultrasonic bath with acetone for several minutes. Images were taken (Figures 5 and 6) and it was determined that dimples were present in the fracture surface that are a characteristic of ductile fracture, Metals Handbook, Volume 12 pg 220.

Hardness

Hardness testing was performed on all bolt shanks. Hardness measurements were taken in the along the shank in the axial direction. The bolt coating was mechanically removed and cleaned. The bolt with identification 'X5' had hardness values taken in the radial direction. This was due to the location of the fracture would not allow the bolt to balance in the hardness tester. The values from the hardness test are found in Table 1.

Table 1 Hardness Values Including Calibration Block Check

Identification	Value 1	Value 2	Value 3	Average
Bolt 1	30.5	35.5	35.5	33.83
Bolt 3	35	36	35.5	35.50
Bolt C	34.5	33.5	36	34.67
Bolt X5	33.5	34.5	33.5	33.83
Calibration Block (63 HRC)	63	63	63	63

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Elemental Composition

Elemental composition was performed using a Leco Combustion/IR to determine carbon and sulfur content. An Inductively Coupled Plasma spectrometer (ICP) was used to determine phosphorus content. Pieces were cut from the sides of the bolt heads for analysis. The elemental composition of the three elements can be found in Table 2 and are within specifications.

Table 2 Elemental Composition of the Bolt Specimens

Identification	% Carbon	% Sulfur	% Phosphorus
Bolt 1	0.382	0.003	0.016
Bolt 3	0.392	0.007	0.016
Bolt C	0.391	0.005	0.017
Bolt X5	0.399	0.006	0.015
Per ASTM A354	0.28 - 0.55	0.040 max	0.045 max

Microstructure

Pieces cut from the bolt head, as described in the Elemental Composition section, were also used for the microstructural analysis. A piece from each bolt was mounted in epoxy, polished and etched with 1% Nital. The specimens were then analyzed and photographed using a metallograph. It was determined that the bolts contained tempered martensite with small amounts of ferrite. (Figures 7-10) This indicated the bolts were quenched and tempered, Metals Handbook Vol. 7 8th Edition pg 30.

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TOUCHSTONE

Conclusion

The analysis of the bolts and bolt sections found that the material used was within specifications for hardness and elemental composition. These values correspond to those obtained by manufacturer. The microstructure analysis concluded that the material was quenched and tempered. Dimples were discovered in the fracture surface of bolt with identification 'X5' which is characteristic of ductile failure.

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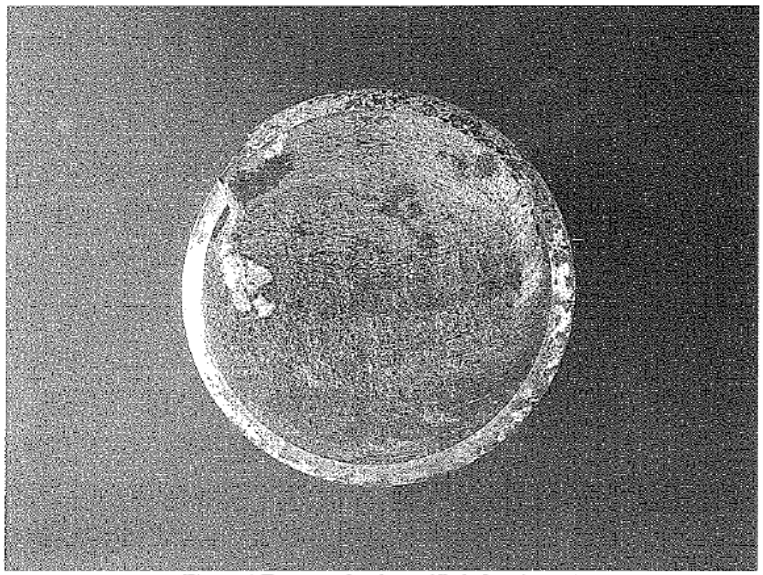

Figure 1 Fracture Surface of Bolt Specimen 1

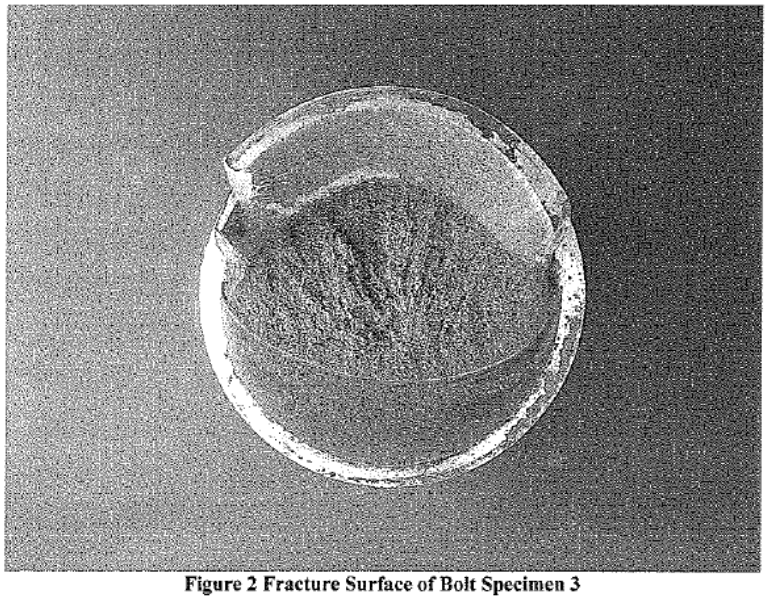

Figure 2 Fracture Surface of Bolt Specimen 3

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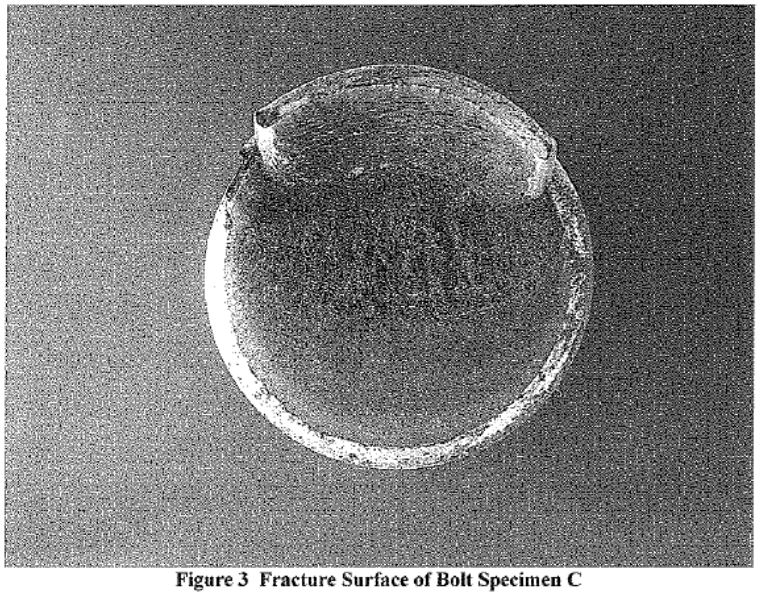

Figure 3 Fracture Surface of Bolt Specimen C

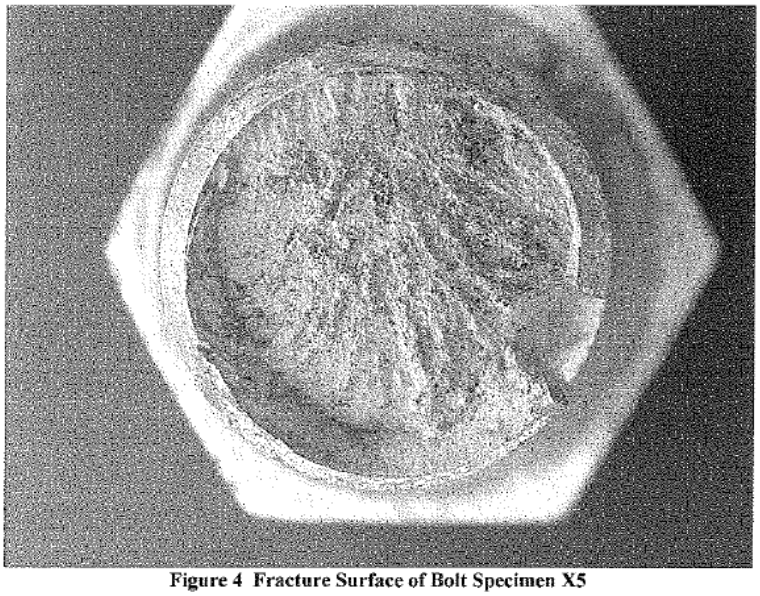

Figure 4 Fracture Surface of Bolt Specimen X5

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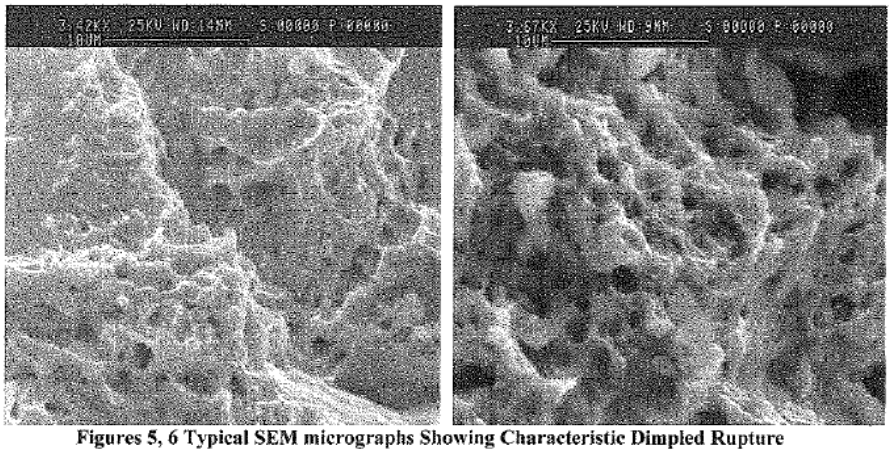

Figures 5, 6 Typical SEM micrographs Showing Characteristic Dimpled Rupture

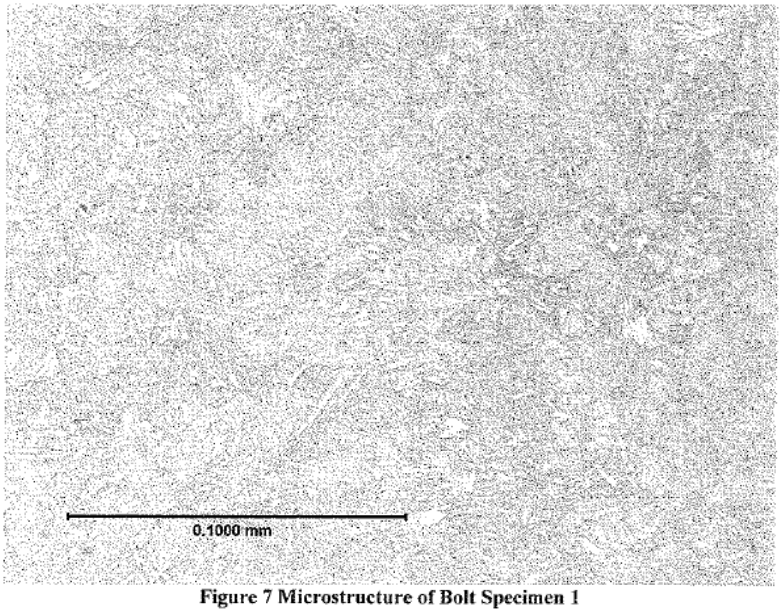

Figure 7 Microstructure of Bolt Specimen 1

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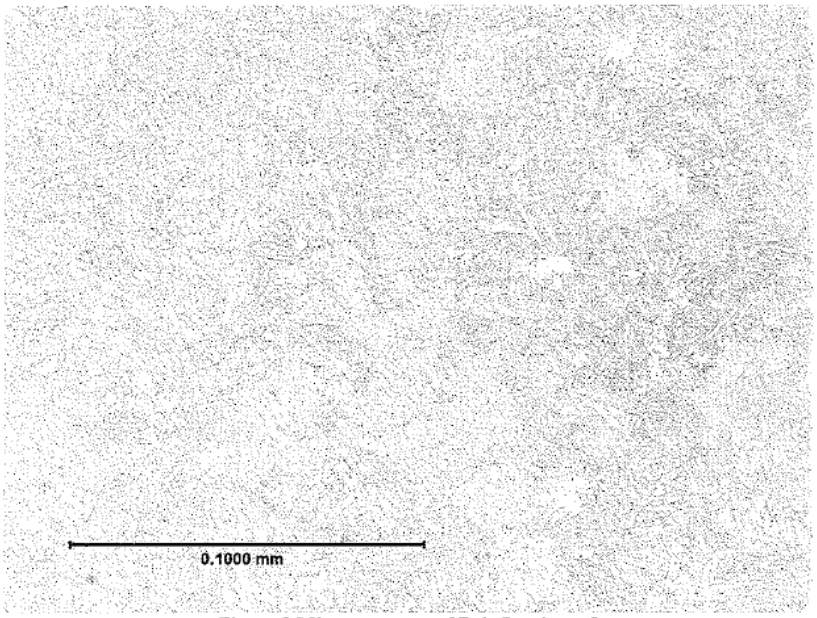

Figure 8 Microstructure of Bolt Specimen 3

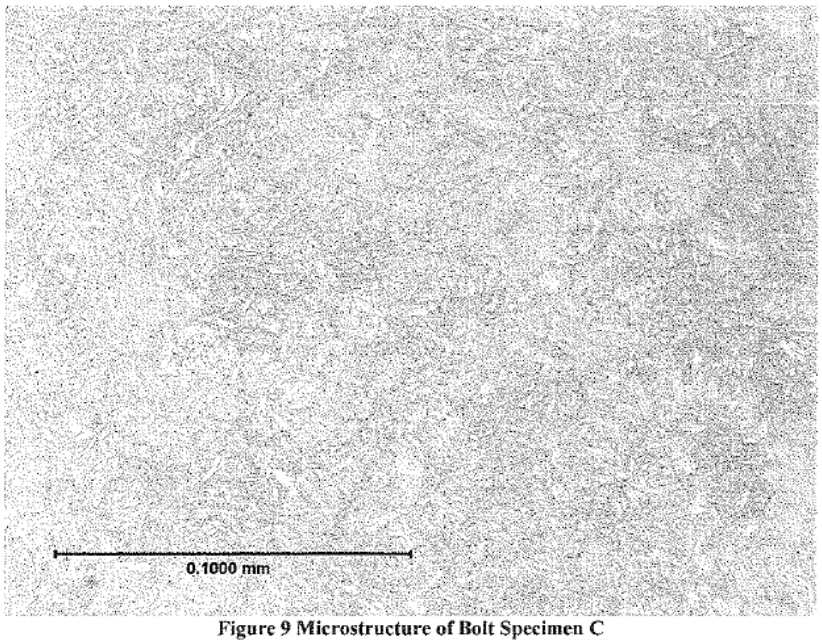

Figure 9 Microstructure of Bolt Specimen C

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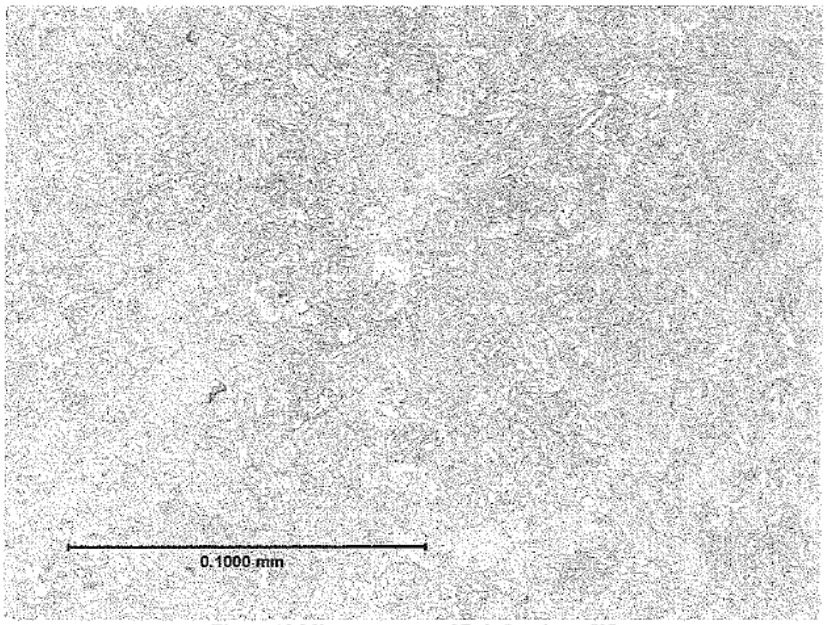

Figure 10 Microstructure of Bolt Specimen X5

Accident Investigation Data - Victim Information

APPENDIX C

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

Event Number: 1 0 0 5 1 1 0

Victim Information: 1

1. Name of Injured/Ill Employee:	2. Sex	3. Victim's Age	4. Last Four Digits of SSN:	5. Degree of Injury:
Deane E. Driscoll	*M*	*50*		*01 Fatal*

6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: *a. Date: 04/18/2007 b.Time: 11:00*

7. Date and Time Started: *a. Date: 04/18/2007 b.Time: 6:40*

8. Regular Job Title: *174 Drill Operator*

9. Work Activity when Injured: *019 Drill operation*

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

11. Experience	Years	Weeks	Days		Years	Weeks	Days		Years	Weeks	Days		Years	Weeks	Days
a. This Work Activity:	3	3	1	b. Regular Job Title:	3	3	1	c: This Mine:	12	0	0	d. Total Mining:	31	10	6

12. What Directly Inflicted Injury or Illness? *089 Broken rock*

13. Nature of Injury or Illness: *140 Severe head injury*

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

15. Company of Employment:(If different from production operator) *Operator*

Independent Contractor ID: (if applicable)

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

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

18. Union Affiliation of Victim: *9000 Other not listed*

Victim Information:

1. Name of Injured/Ill Employee:	2. Sex	3. Victim's Age	4. Last Four Digits of SSN:	5. Degree of Injury:

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

7. Date and Time Started

8. Regular Job Title:

9. Work Activity when Injured:

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

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

12. What Directly Inflicted Injury or Illness?

13.Nature of Injury or Illness:

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

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

Independent Contractor ID: (if applicable)

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

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

18. Union Affiliation of Victim:

Victim Information:

1. Name of Injured/Ill Employee:	2. Sex	3. Victim's Age	4. Last Four Digits of SSN:	5. Degree of Injury:

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

7. Date and Time Started:

8. Regular Job Title:

9. Work Activity when Injured:

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

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

12. What Directly Inflicted Injury or Illness?

13. Nature of Injury or Illness:

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

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

Independent Contractor ID: (if applicable)

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

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

18. Union Affiliation of Victim: