

The Technology Used to Investigate Some Mine Fire and Explosion Accidents

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ABSTRACT

The investigation of a mine fire or explosion to determine the cause is often a difficult and complex task. Generally, evidence is lost by the combustion process that takes place. In addition, the environment may be confining, such as in an underground coal mine, which presents difficult circumstances in examining the site of the fire or explosion and collecting evidence. In any fire or explosion, the preservation and collection of evidence is paramount for there to be any chance of determining the cause. The investigative work is analogous to the work of a detective. Various pieces of information and findings are compiled in an attempt to determine the cause of the fire or explosion and to develop safety measures to prevent the occurrence of similar incidents. Methods used to investigate a mine fire or an explosion are similar to those used in the investigation of industrial or residential fires or explosions.

Procedures have been established by the U. S. Mine Safety and Health Administration (MSHA) to systematically conduct a mine fire or explosion investigation. MSHA uses field and laboratory methods to examine the evidence from a mine fire or explosion. In some cases, sophisticated laboratory equipment such as an electron microscope or an optical stereo microscope are used to examine evidence recovered from a mine fire or explosion. At times, a simulation or attempted recreation of the accident event may be utilized to show how the event may have occurred. A selection of mine fire and explosion incidents is presented to illustrate the laboratory and accident scene recreation techniques used in the investigation, the findings obtained, and the conclusions derived.

INTRODUCTION

The reporting of a mine accident is specifically defined in Title 30, Code of Federal Regulations, Part 50¹. Reporting is based on the definition of accident which is specified in Part 50. The definition of “accident” as it pertains to a fire or explosion event can involve one or more of the following: (1) a death of an individual at a mine; (2) an injury to an individual at a mine which has reasonable potential to cause death; (3) an unplanned ignition or explosion of gas or dust; (4) an unplanned mine fire not extinguished within 30 minutes of discovery.

When an explosion or an unplanned mine fire that is not extinguished within 30 minutes of discovery occurs in the U.S. mining industry, the mine operator is required to immediately notify MSHA. The mine operator is also required to investigate the accident and to preserve the accident site or accident related area. The Mine Safety and Health Administration will decide whether to conduct an accident investigation. If MSHA decides to conduct an investigation, it will initiate the investigation within 24 hours of receiving notification of the accident.

INVESTIGATION STRATEGY

The investigation of a mine fire or explosion to determine the cause is a complex task. Evidence may be destroyed by the fire or explosion. In addition, the environment may be confining, such as in an underground coal mine, which presents difficult circumstances in examining the site of the fire or explosion and collecting evidence. The site of the incident must be secured to protect evidence and the scene. Safety and health hazards from the fire or explosion event and the investigation that follows need to be adequately addressed. In any mine fire or explosion, the preservation and collection of evidence is paramount for there to be any chance of determining the cause.

The basic methodology of the investigation of a mine fire or explosion follows a systematic approach that is similar in respect to methods specified by NFPA 921 - Guide for Fire and Explosion Investigations² and by investigators such as Kennedy³, DeHaan⁴, Noon⁵, and Redsicker and O'Connor⁶. As a means toward ensuring effective and efficient investigations, MSHA has established accident and illness investigation procedures and published them in a handbook⁷.

The investigative work on a fire or explosion incident is analogous to the work of a detective. The procedures used by a fire or explosion investigator are quite similar to those used by a detective investigating a case. Furthermore, the analysis of the evidence and information can encompass several scientific disciplines including the use of forensic engineering principles and methodology. Various pieces of information and findings are compiled and scrutinized in an attempt to discover the cause of the fire or explosion. The findings from the investigation are used to develop and implement safety measures to prevent the occurrence of similar incidents. The goal of each and every mine fire or explosion investigation should be to determine the origin and cause. Realizing that goal helps in the formulation of adequate and appropriate preventative measures.

The investigation of a mine fire or explosion has features that are common to the investigation of industrial or residential fires or explosions. Although each mine fire or explosion is unique, procedures as previously indicated have been established to systematically conduct a mine fire or explosion investigation. In essence, the steps to be followed are derived from the "Scientific Method" described in NFPA 921, Chapter 4, which is to: (1) identify the problem (2) define the problem (3) collect data (4) analyze the data (5) develop a hypothesis (6) test the hypothesis (7) select the final hypothesis.

Both field and laboratory methods are used to examine the evidence from a mine fire or explosion. In a mine fire or explosion investigation, there are instances where tests are performed on the evidence. Well-known standard methods, including the American Society for Testing and Materials standard tests for determining flash point, ignition temperature or flame spread may be used. Typically, a test protocol is developed. The test protocol indicates the type of test or tests to be conducted, the equipment and resources needed to perform the test or tests, the parties needed to conduct the test(s), the parties desiring to witness the test(s), the time constraints, and the costs. In some cases, nonstandard methods or sophisticated laboratory techniques which involve chemical and thermal analysis, flammability tests, an electron microscope and/or a stereo or optical microscope are used to examine evidence recovered from a mine fire or explosion. Experiments may be designed to recreate the accident event, or a simulation of the accident event may be utilized to show how the actual event may have occurred. These techniques can provide valuable insight into the accident event and can also serve as a demonstration or teaching tool.

Several investigations of mine fires and explosions as indicated in Table 1 are presented to show the value of the techniques used in the investigations, the findings obtained and the conclusions derived. The selection of accident events in Table 1 was made to encompass both surface and underground mines, as well as associated surface plants and facilities.

Table 1 – Mine Fire-Explosion Events Used to Illustrate Examination of Evidence

Event	Type of Mine	Findings	Fatalities
Tire explosion	Surface sand and gravel	Heat applied by torch to a tire rim causing generation and ignition of combustible gases inside the tire	1
Tire explosion	Surface limestone quarry	Torch used to cut drum off tire assembly causing generation and ignition of combustible gases inside the tire	1
Explosion in a shaft	Underground coal (shaft sinking)	Cutting of metal sheeting with a torch ignited accumulated methane-air mixture	3
Explosion of an equipment cylinder	Surface gypsum	Torch used to free cylinder caused internal explosion of vapors from penetrating oil injected into cylinder	1
Fire in a surface plant	Coal preparation plant	Torch used to cut bolt produced sparks which ignited coal dust-alcohol mixture	0
Conveyor belt fire	Underground salt	Belt rubbing on steel frame caused heating and subsequent fire	0

EXAMPLES OF TESTS OF EVIDENCE FROM ACCIDENT EVENTS

Tire Explosions At Surface Mine Operations

A tire explosion occurred during an operation to repair the brakes on a bottom dump trailer⁸. A contract employee assigned to repair the brakes on the trailer was unable to remove the tire/rim assembly by mechanical means. He then used an oxygen/acetylene torch to apply heat to the rim of the tire. After about 45 minutes to an hour, the tire exploded and fatally injured the contract employee. The tire was examined to pinpoint the cause of the explosion. A section that showed apparent heat damage was cut out of the tire (see Figure 1) and the rubber liner from that section was tested in the laboratory by using a differential scanning calorimeter (DSC). The DSC test produced thermograms showing the exothermic behavior of the undamaged liner and a portion of the liner that had apparent heat damage. The analysis of the DSC data determined that the liner exhibiting heat damage was exposed to a temperature exceeding 425°C (797°F). The laboratory analysis showed that the tire material decomposed and produced hot embers and a combustible gas mixture within the tire. The heated tire material provided an ignition source for the combustible gases which subsequently ignited, causing the tire to explode. It was calculated that the tire explosion created a maximum pressure of about 22.4 bars (325 pounds per square inch).

Another tire explosion occurred at a surface mine crushed limestone operation⁹. An employee used a torch to cut the drum off of a tire assembly. While prying the cut drum with a pry bar, the tire exploded fatally injuring the employee and injuring two other employees. As shown in

Figure 2, the explosion turned the tire completely inside out and sent pieces of the sidewall in all directions. Laboratory analysis was performed on the tire material and an actual torch cutting test was performed on the tire rim to simulate the torch cutting as used prior to the explosion of the tire. The torch transferred sufficient heat to ignite material within the tire, generating combustible vapors and increased internal pressure. The smoldering material inside the tire served as the ignition source that ignited the combustible vapors within the tire causing it to explode.

Shaft Explosion

An independent contractor was developing a vertical shaft to a coal mine when an explosion occurred near the bottom of the shaft¹⁰. Three miners were fatally injured and three other miners were injured. Prior to the explosion, the miners were working on an elevated work deck, attempting to remove corrugated, galvanized steel sheeting. The sheeting blocked access to the unventilated water ring being constructed. The shaft was about 289 meters (950 feet) deep and within 9 meters (30 feet) of intersecting the coal seam. The miners partially opened the steel sheeting with an axe and then a hand-held methane detector was placed into the opening to test for methane. After reading 0.2 percent methane on the detector, a miner used an oxygen-acetylene torch to cut the steel sheeting. An explosion occurred when an explosive methane-air mixture contained inside the water ring was ignited by the torch cutting process. Numerous items were taken as evidence from the site. One piece of evidence in particular was the corrugated, galvanized steel sheeting. The sheeting was examined in the laboratory using a stereo microscope and showed evidence of cutting as indicated in Figure 3. A reference sample of corrugated, galvanized steel sheeting was cut with an oxygen-acetylene torch of the type used by the fatally injured miner. The reference sample was used for comparison with the galvanized, corrugated steel sheet recovered from the accident. As part of the investigation, the microscopic examination of the steel sheeting from the accident and comparison with the reference sample provided evidence that the steel sheeting blocking access to the water ring was apparently cut with an oxygen-acetylene torch.

Explosion In An Equipment Cylinder

An explosion of a suspension cylinder on a haulage truck occurred at a surface gypsum mine¹¹. The explosion propelled the 0.6 meter (25 inch) long, 0.2 meter (7 inch) diameter cylinder rod, striking and fatally injuring a miner. The miner had broken off a nitrogen charging valve on the cylinder. A penetrating lubricant was sprayed into the cylinder to loosen the remaining threads of the broken valve. The lubricant failed to loosen the remaining threaded piece. Heat from an oxygen-acetylene torch was then used in an attempt to loosen the remaining threaded piece. The heat from the torch ignited the combustible vapors of the penetrating lubricant in the cylinder, causing an explosion which propelled the cylinder rod that struck the miner. The cylinder assembly was taken from the accident as evidence. A laboratory experiment was set up with the cylinder assembly. The penetrating lubricant that was used in the accident was sprayed into the nitrogen charging valve port. Subsequently, the flame from an oxygen-acetylene torch was directed onto the nitrogen charging valve port. An explosion occurred, forcefully propelling the cylinder rod as shown in Figure 4. The laboratory experiment provided conclusive evidence of the cause of the explosion in the suspension cylinder. The laboratory experiment subsequently served as a training and educational tool for accident prevention.

Coal Preparation Plant Fire

A devastating fire occurred in a coal preparation plant¹². Fortunately the mine employees working in the plant were able to escape the fire without any injuries. A mine employee used a

torch to cut a bolt off of a floatation cell that was located on the second floor of the plant. The fire was caused by molten metal and/or sparks igniting a mixture of coal dust and alcohol which had accumulated on the top of and around two clay settling tanks located on the first floor and off to the side of the torch cutting operation. Alcohol had been spilled during a filling operation about a week prior to the fire. The fire consumed a 1400-gallon tank of alcohol that was located near the clay settling tanks. The fire also consumed most of the two 1000-gallon clay settling tanks. These tanks, located on the lower floor, were within the travel distance of sparks generated from the cutting operation. Initially, it was presumed that spilled alcohol was ignited by sparks from the cutting operation. However, a mixture of coal dust and alcohol was shown to ignite more readily in experimental tests. The tests were set up to simulate the cutting of a metal rod with the generation of sparks which landed on containers holding a thin layer of alcohol and a thin layer of coal dust-alcohol mixture. The experimental tests served as the basis for determining the cause of the fire. Figure 5 illustrates the test showing the ignition of the coal dust-alcohol mixture.

Conveyor Belt Fire In An Underground Salt Mine

A fire involving a conveyor belt occurred in an underground salt mine¹³. Fortunately, there were no injuries from the fire. The fire occurred as a result of a misaligned conveyor belt rubbing against a steel beam of the conveyor structure. The misaligned conveyor belt caused a jam at the take-up pulley. The fire burned approximately 30.5 meters (100 feet) of conveyor belt, but the fire also spread to a transfer conveyor belt. Eight-five meters (280 feet) of the transfer conveyor belt was consumed by the fire. As part of MSHA's investigation, an examination was made of a segment of the misaligned belt recovered from the fire to determine if the belt was under load and tore apart. By visual examination, the tears in the partially burned edge of the segment indicated the belt was under load and burning occurred near the center and the belt tore apart from the center toward the edges. This explanation was confirmed by microscopic examination of a section of the segment; unburned strands of the ply material broken from tension were observed as indicated in Figure 6.

SUMMARY

A body of knowledge has been gained from the investigation of mine fire and explosion accidents. The technical data obtained comprise only one portion of the information needed to successfully investigate a fire or explosion incident. Basically a systematic procedure which follows the scientific method provides the best strategy for investigating such incidents. Some of the various methods used to examine and test evidence and reconstruct accident events have been illustrated. The knowledge and experience gained from the investigation of mine fires and explosions incidents continues to broaden and improve. Newer technology and testing methods which includes modeling and large-scale experiments continue to be undertaken and developed¹⁴. The newer tools and methods may have application and be subsequently adapted for use in mine fire and explosion accident investigations.

REFERENCES

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Figure 1 – Burned Area of a Mine Vehicle Tire that Exploded



Figure 2 – View of an Exploded Mine Vehicle Tire



Figure 3 – Galvanized Steel Sheet Covering a Man Door Opening in a Coal Mine Shaft

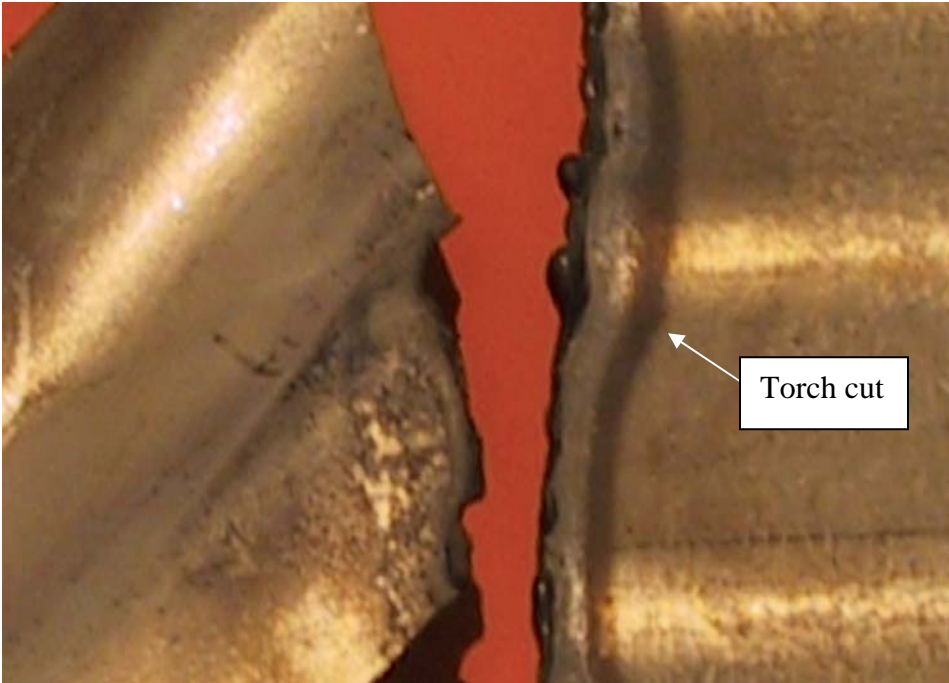


Figure 4 – Empirical Test Illustrating an Explosion in an Equipment Cylinder



Figure 5 – Experiment Showing Sparks from Cutting Torch Igniting Coal-alcohol Mixture

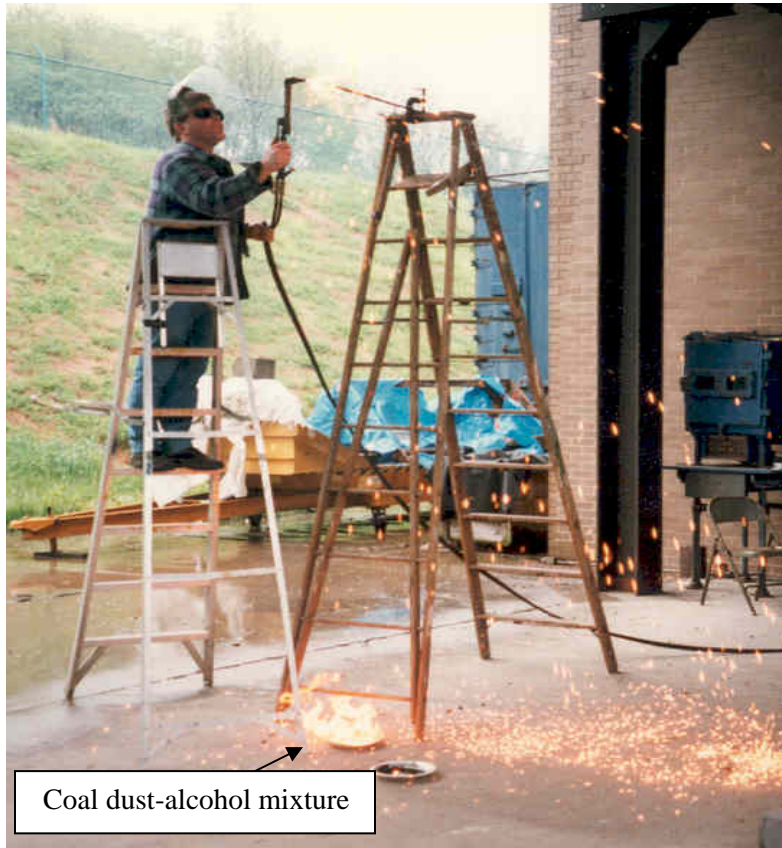
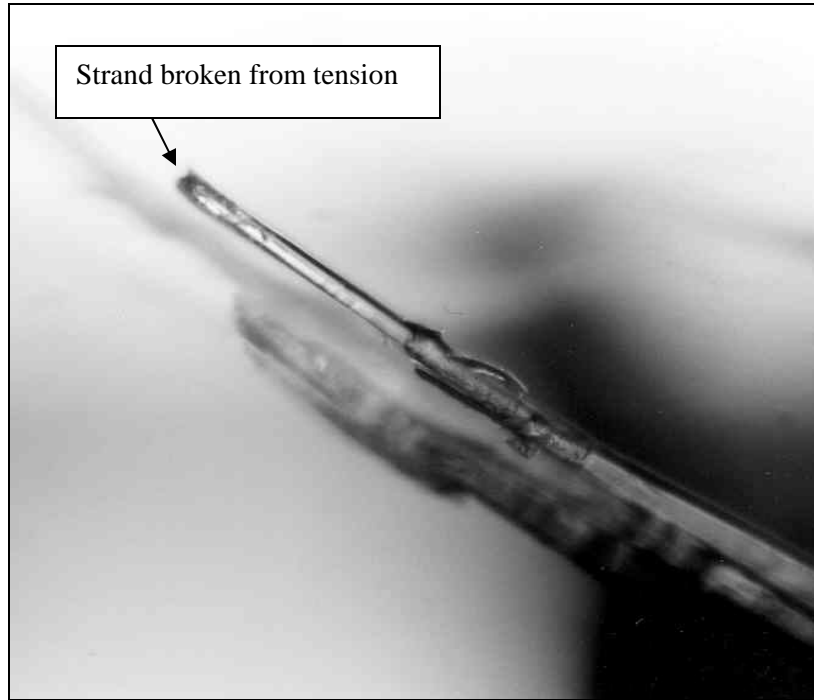


Figure 6 – Microscopic Examination of Strand of Ply Material from Conveyor Belt



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