A Summary of U. S. Mine Fire Research

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ABSTRACT

Since 1910, the U. S. Bureau of Mines and NIOSH has conducted research to eliminate fires in underground mines. Early studies concentrated on the investigation of the causes of mine fires and recommendations for preventing fires, spontaneous combustion, and mine fire rescue, all of which served to improve safety in mines. In the 1950's, research characterized the flammability of gases, dusts, and vapors. The 1960's brought an emphasis on mine fire prevention, the hazards of combustible materials used in mines, and mine fire extinguishment methods. Results from these studies formed the basis for fire prevention regulations contained in the 1969 Coal Mine Health and Safety Act. The 1969 Act also greatly expanded the Bureau of Mines' role in coal and metal/nonmetal mine fire research. This led to a significant reduction in the severity and incidence of mine fires. The MINER ACT of 2006 placed a renewed emphasis on research in the areas of mine fire prevention, detection, control, and extinguishment. This paper summarizes the highlights of the Bureau of Mines and NIOSH fire research program since 1910 and describes current research to reduce or eliminate the hazards of fires in mines.

INTRODUCTION

Mine fires have always been a serious hazard in mining. One of the contributing factors in the call for the establishment of the U.S. Bureau of Mines was the Cherry Mine fire in Illinois in 1909 (Keenan 1963). This disaster took the lives of 259 miners. In the years preceding the Bureau of Mines, there were an average of about 500 fires per year. Fires continue to be a serious hazard to the health and safety of our Nation's mining workforce. From 1990 through 2001, there were 1,060 fires, resulting in 560 injuries and 6 fatalities at U.S. mine operations (DeRosa 2004). As recently as 2006, a fire in an underground coal mine in West Virginia claimed two lives. From the Bureau of Mines inception in 1910, through today under NIOSH, the United States has conducted a rigorous research program to reduce the fire hazards in mining. Through the years, the emphasis has focused on making mines safer through improved fire prevention, detection, control, and extinguishment methods. There have been many tangential benefits from this research, including improvements in fire safety in the transportation, defense, and space industries, to name a few. This paper will describe the progress made in mine fire safety through the history of the Bureau of Mines and NIOSH.

THE EARLY YEARS

The genesis of the U.S. Bureau of Mines is well documented in other papers and books (Kirk 1994). Briefly, the Bureau's scope included "investigations into the methods of mining, especially in relation to the safety of miners, and the appliances best adapted to prevent accidents; the possible improvement of the conditions under which mining operations are carried on; the treatment of ores and other mineral substances; the use of explosives and electricity; the prevention of accidents; and other inquiries and technological investigations pertinent to said industries" (U.S. Public Law 179). Initially, the Bureau conducted a country-wide study of mine fires and mine fire hazards, including mine accident investigations, to find the cause of fires, means to prevent fires, and to determine the oxidation rate of coal in mine air. Another early interest in fire research was in the spontaneous heating during coal storage. Large amounts of coal were stockpiled by the government for heating of government buildings and powering naval boats. Though largely for economic reasons, this research laid the groundwork for spontaneous combustion prevention in underground coal mines.

The early investigations of the causes of coal mine fires showed the importance of proper equipment and methods for preventing and fighting coal mine fires. The first causes were identified as the careless handling of open lights, short circuits in electrical equipment, improper fuel storage practices, the use of long-flame explosives, the lighting of accumulations of gas, and spontaneous heating. Note the open flame cap lamp on the miner in Figure 1. Early recommendations included the use of permissible explosives, the use of electrical lamps for illumination, better ventilation in the working areas, the guarding of trolley wires, fireproofing of shaft stations, and the use of wire rope to replace hemp rope (Rice 1912). Prior to 1941, the Federal government was prohibited from inspecting mines or enforcing recommendations. After the Cherry Mine disaster, the state of Illinois drafted the most complete code for fire protection in mining at the time. This code included the need for adequate fire-fighting equipment, including hose lines, water tanks and hydrants, portable extinguishers, telephone and alarm apparatus, breathing apparatus, ventilation fans, and mine fire escape plans.

Figure 1. Miner with open flame cap lamp for illumination

A critical component after a mine fire or explosion in the early 1900's was evaluating the mine atmosphere in order to re-enter safely for rescue of miners and for post-accident investigation. Gas analysis at the time was rudimentary and facilities for analyzing gas samples were far removed from mine sites. Research was completed in 1913 on a gas detector for determining inflammable gases (Burrell and Siebert 1913). By 1921, The Bureau of Mines equipped railroad cars, shown in figure 2, with the latest technology in mine rescue apparatus, first aid equipment, and gas analysis equipment and stationed them in 10 mining districts throughout the country. These cars were used for first aid and mine rescue training during normal circumstances, and immediately deployed to the mines during emergencies.

Figure 2. Bureau of Mines mine rescue and training car

By 1921, the Bureau's role in fires was still primarily as an accident investigations branch with no dedicated fire research program. As a result of World War I, several new areas of interest emerged. A program on metal dust fires studied the fire hazards of shipping metal dusts, including aluminum and zinc. The use of gas masks, developed in large part by the Bureau for the Army during the war (Farrow 1920) , was examined for use in fighting fires. Of course, the filters removed smoke particles, but did not remove carbon monoxide or provide oxygen. This led to research on carbon monoxide filters and to the development of carbon monoxide detectors. It was found that carbon tetrachloride and foamite fire extinguishers, typical of the time, produced hydrochloric acid and phosgene (Fieldner and Katz 1921). Studies continued on spontaneous combustion during coal storage (Hood 1922). It was determined that coal characteristics such as coal type, moisture content, and pile size contributed to the spontaneous combustion hazard. Other research findings during the 1920's included the determination that rock dust could readily extinguish a coal fire when the miner was able to fight the fire directly (Howarth and Greenwald 1927), and that a hot surface could ignite methane (Leitch et al 1925).

Flammability laboratory

In 1924, a cooperative arrangement was started between the Safety in Mines Research Board of Great Britain and the Bureau of Mines to deal with the prevention or abatement of accidents in mines. Part of this program included the determination of the limits of flammability and explosibilty of gases and dusts encountered in mines and the mineral industries. Dr. Coward of England and Dr. G. W. Jones of the Bureau of Mines led this program. Dr. Coward stated that "this knowledge is of fundamental importance in the study and prevention of mine fires and explosions." In 1929, a flammability laboratory was set up in Pittsburgh, PA to determine the inflammable limits of methane and of the distillation products of coal in air. A gas flammability apparatus is shown in figure 3. The laboratory also studied other natural and manufactured gases used as anesthetics, refrigerants, fumigants, insecticides, and solvents. Initial studies were completed on ethylene, ethyl ether, ethylene dichloride, vinyl chloride, carbon disulfide, pentane, benzol, acetone, furfural, and ethanol for the purpose of preventing gas fires and explosions in the metallurgical, petroleum, gas-manufacturing, and related industries. By 1952, the laboratory had completed studies of 155 dusts and gases. In 1952, a comprehensive report of all data was published (Coward and Jones 1952).

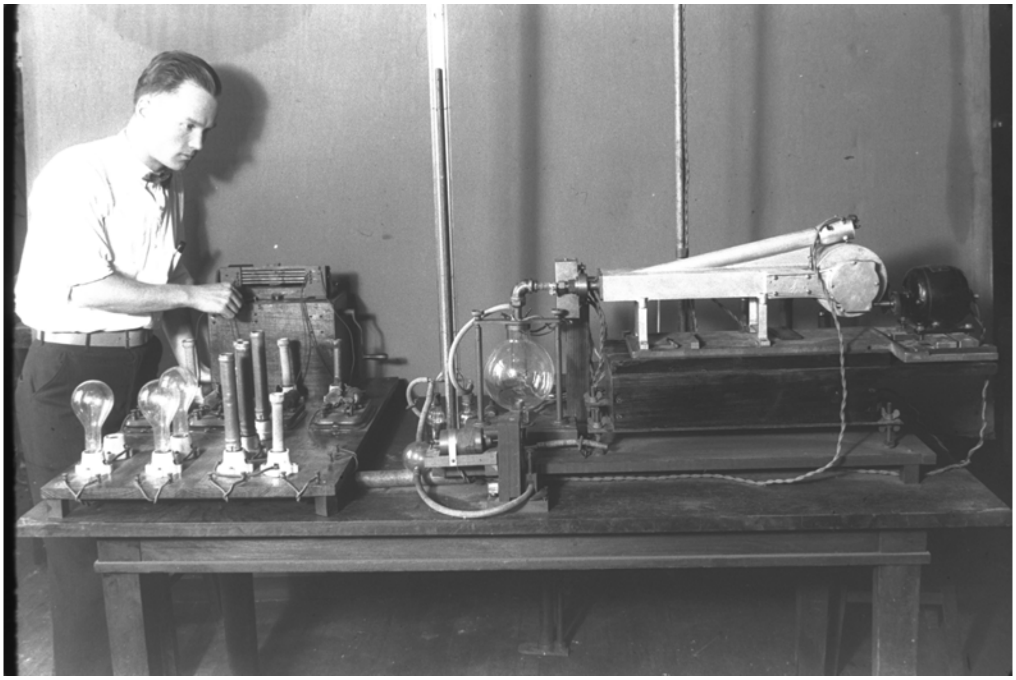

Figure 3. A gas flammability apparatus

The 1930's

In 1931, there were 21 fires and 1 fatality due to fires. Overall, there were 1430 mining fatalities. With the Great Depression affecting the whole country, and the government not immune, Director Turner did his best to fend off budget cuts. Director Turner, in his 1932 report to the Secretary of Commerce, compared the 1931 statistics to the annual average of 2409 fatalities in the 25 years prior, and stated "Various factors are undoubtedly responsible for the excellent safety record in 1931, but doubtless the activities of the Bureau of Mines had a vital influence" (Turner 1932) In 1934, the Bureau's budget was cut to one-half of the 1928 funding level, and coal mine fire and coal dust explosion research was limited to just a few explosion demonstrations.

In 1936, a new laboratory investigation was started to study the causes, behavior, and control of mine fires. The Bureau began collecting extensive data on the atmospheric composition of gases during mine fires. The Bureau's gas laboratory is shown in figure 4. A chemical method for locating fires in mines based on gas data (Ash and Felegy 1948), and a study of the mechanism of flame propagation in mine entries was initiated (Godbert and Greenwald 1936). Improvements were also made in the use of ventilation to eliminate gas accumulation hazards.

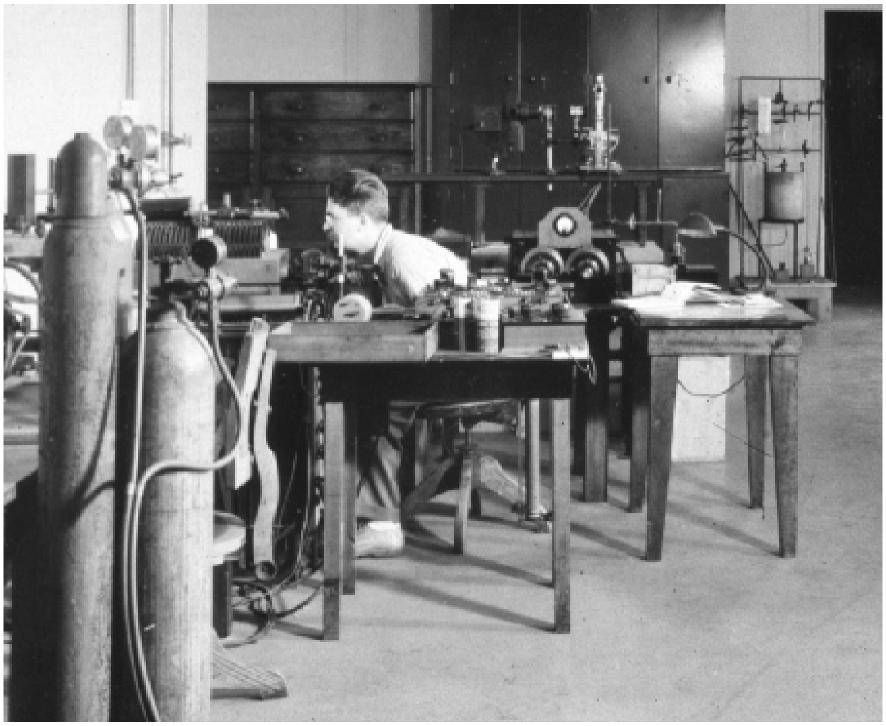

Figure 4. Early Bureau of Mines gas laboratory

Mine Investigations and Inspections

Prior to this time, the Federal government had jurisdiction to investigate mine accidents only for the purpose of determining the cause and means to prevent the accidents, and to assist in any recovery operations. In 1931, the Director of the Bureau of Mines, Scott Turner, stated in his Annual Report to the Secretary of the Commerce, that "fires are generally preventable, and that data from investigations are confidential. So there is lack of knowledge/appreciation of dangerous practices and conditions." Turner stated that he was "going to ask Congress to allow publication with conclusions and recommendations so that they can be put into effect." (Turner 1931) In 1938, reports on recent mine fires (Harrington and Fene 1938) and recent lab research (Fieldner 1938) were published. Both reports emphasised recommendations to improve safety in mines. In 1941, Congress approved the Coal Mine Inspection Act, a year after 257 miners died in four separate explosions. The 1941 Act now allowed the Federal government to inspect mines for the purpose of making recommendations to improve safety. Initially, there were 107 Federal mine inspectors and over 14,000 coal mines. In 1946, agreement was reached between the John L. Lewis of the United Mine Workers Union and Julius A. Krug, the Secretary of the Interior, to make compliance with Federal recommendations mandatory based on the 1946 Federal Mine Safety Code. In the 1947 Annual Report to the Secretary, Bureau of Mines Director Sayers stated that "thousands of safety improvements were made in U.S. mines as a result of the Krug-Lewis agreement" (Sayers, 1947).

World War II

During the months prior to the United States' involvement in World War II, the Bureau of Mines diverted its efforts into gearing up for war. There was an abnormal demand for metals and minerals, particularly to make steel. During the war years, Bureau scientists worked to supply the Nation with mineral commodities. The Bureau's fire scientists tested western coals for making coke. They studied the flammability of metallic dusts used in bombs and methods for extinguishing burning powders. They also conducted training in the extinguishment of incendiary bombs. Because of the need for synthetic rubber, the Bureau conducted flammability studies of rubber-making chemicals, such as butadiene, styrene, acrylonitrile, chlorobenzene, and trichloroehtylene to ensure safety in the rubber-making process. Research was also conducted on the detection of atmospheric contaminants that might be encountered on the battlefield. This work had significant mining application after the war in the improvement of mine gas detection devices.

POST-WAR YEARS

The post-war years featured a much larger emphasis on mine safety research as a whole, including fire research. The 1946 Federal Mine Safety Code giving the Bureau of Mines the right to inspect and enforce mandatory compliance with the Code, combined with the technological advances from the war effort, led to a marked increase in safety research. A research study was conducted on the efficacy of various materials and methods for extinguishing coal mine fires (Howarth et al 1949). In 1947, the Bureau was working on the development of diesel equipment in underground mines as a means to eliminate electrical hazards associated with electrical trolley lines. The first approval of a permissible diesel locomotive for underground use occurred in 1951. In addition, the Bureau conducted classified research through the 1940's for the Navy on gas-indicating devices, which led to improvements in mine fire detection.

The Bureau of Mines celebrated its 40th anniversary in 1950 by reorganizing into three divisions; Minerals, Fuels and Explosives, and Health and Safety. In 1950, there were still 593 fatalities in the mining industry. The Bureau decided that they would investigate all fatalities with a view to determining preventive measures. Prior to 1950, they had only investigated major disasters, defined as having more than 5 fatalities. In 1951, there were five major coal mine disasters, including the Orient Mine disaster in Illinois, which killed 119 and was the worst disaster since 1928 (Keenan 1963). This led to the 1952 Federal Coal Mine Safety Act, and authorized Federal inspectors to act to prevent disasters in all mines with greater than 15 underground workers.

In the early 1950's, the Bureau conducted extensive studies on the fire resistance of conveyor belting, hydraulic fluids and electrical cables to determine their fire hazards. An important milestone was reached in 1955 when the Bureau prescribed a schedule of acceptance requirements for fire resistant conveyor belting (Schedule 28). By 1958, 60 conveyor belts were accepted as fire resistant. Flame resistance tests were also conducted on 20 electrical cables and on fire resistant hydraulic fluids, and the first testing on frictional ignition of conveyor belts was completed. In 1958, suppression tests of high expansion foam plugs to extinguish large-scale coal and mining machinery fires were started at Bruceton, Pa. Figure 5 shows a coal mine fire in the Bruceton Experimental Mine just prior to extinguishment. By 1960, the Bureau had completed six extinguishment tests of 15 ton coal fires and demonstrated the results to the coal industry. This resulted in the employment of portable foam generators at mines throughout the United States (Nagy et al 1961).

Figure 5. A 15-ton coal fire prior to extinguishment with high-expansion foam

Fundamental Combustion Research

An integral part of the Bureau of Mines fire research program throughout the 1940's and 1950's was the fundamental combustion research program. In 1948, researchers began a study of the mechanism of ignition, propagation, and stabilization of flame and flame quenching. The research contributed significantly to the fundamental knowledge of combustion, fluid dynamics, kinetics, and thermodynamics. Among the accomplishments were an understanding of laminar and turbulent flames; kinetic studies of the oxidation of various hydrocarbons, important in understanding the theory of combustion; an experimental technique for measuring burning velocities of turbulent flames at low pressures, which was useful in the design of jet engine combustors and rockets; and burning velocity measurement at above-atmosphere pressures. An instrument to measure turbulent flame structure is shown in figure 6. The results of this research also had direct application to the understanding of coal mine fire and explosion behavior. In 1951, Bernard Lewis and Guenther von Elbe of the Bureau of Mines published the seminal book "Combustion, Flames and Explosions of Gases" (Lewis and von Elbe 1951). This book had two subsequent editions, the latest in 1987, and is still widely used as a graduate textbook for combustion science. In 1954, Lewis was instrumental in founding the Combustion Institute, in Pittsburgh, Pa. This international organization is an educational, non-profit scientific society whose purpose is to promote and disseminate research in combustion science. The organization publishes the journal, Combustion and Flame, and holds the International Combustion Symposium every two years.

Figure 6. An apparatus to measure turbulent flame structure

1960's

Experiments continued in the early 1960's on coal mine fire control. The efficacy of various fire extinguishing agents and application methods of these agents were examined on simulated mining machines (Mitchell et al 1961). These studies included water and alkali metal salts or wetting agents, water fog, and the remote application of high expansion foam. Experiments and field trials were conducted with rigid polyurethane foam for sealing mine openings, controlling ventilation, and combating mine fires (Mitchell et al 1964). This investigation also required testing of the flame-retarding and toxic properties of polyurethane Mitchell et al 1966). The first ventilation studies using the Bureau's fluid network analyzer for contaminant spread were completed in 1962. That year also included the first evaluation of health and safety, including fire hazards, in metal/nonmetal mines.

The mid-1960's saw the introduction of longwall mining into the United States, and the need to evaluate the effect of this new technology on fire hazards. The first investigations into the effect of air velocity on a burning conveyor belt were started in 1964. Also included in this study was the determination of types of contaminant gases produced by the fires for detection (Mitchell et al 1967). With the increased mechanization, new fluids were introduced into the mines. A special report was published on the ignitibility and flammability of more than 80 lubricants, hydraulic fluids, and engine oils used in mines. Auto-ignition temperatures were measured for these fluids at pressures up to 15,000 psig (Zabetakis 1965). In 1968, a new approach to the concept of the extinguishment of fires was started to gain a better knowledge and understanding of the mechanism of inerting in the prevention of fires. This program was fundamental in nature, and made significant advances in the mechanism of flame inhibition (Biordi et al 1973).

The Bureau of Mines also contributed significantly to the space program in the 1960's. Researchers were asked by NASA to develop solutions to the problem of extinguishing fires in space vehicles, venting to low pressures, and the flammability characteristics of a variety of rocket propellant combinations, including studies in high vacuum for vehicle attitude control. The Bureau was also asked to assist in the investigation of the tragic Apollo 1 fire, studying the fires in oxygen-rich environments. The results of the Bureau's investigation showed that a treatment for flame proofing space fabrics may actually enhance the ignitibility or flammability of the material (Kutcha et al 1969).

FEDERAL COAL MINE HEALTH AND SAFETY ACT OF 1969

In 1968, a series of explosions at the Farmington No. 9 Mine in Mannington, WV killed 78 miners. This disaster prompted a renewed demand for improved safety measures in coal mining and led to the Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173). Congress said in the preamble that "the first priority in mining must be the health and safety of its most precious resource – the miners." The legislation directed the Bureau to conduct research and development needed to eliminate coal mining hazards and reduce the risks of health impairment, injury, or death. The 1969 Act led to the development of mandatory safety standards in 1970. At that time, the Bureau health and safety program was reorganized to strengthen enforcement, and a Health and Safety Technical Support Center was created for approvals and testing of mine equipment and materials, including fire resistance. In 1973, the enforcement function and Technical Support Center was moved into the newly created Mine Enforcement Safety Administration (MESA), the precursor to the Mine Safety and Health Administration (MSHA).

1970's

The new law greatly expanded the Bureau's role in coal mine fire research. In 1971, contract research was initiated to develop methods of remote sealing, fire detection, automatic fire suppression on mining equipment, and to evaluate suppression systems in conveyor belt entries. The results of these studies led to many of the in-mine detection and suppression systems still used today. In-house research continued on studying the reaction mechanism of flame inhibition, the early detection of smoke and fire in underground mines, and the efficacy of various extinguishing agents to fight coal mine fires.

In 1972, the Sunshine Mine fire at a silver mine in Kellogg, Idaho killed 91 miners. This led to an increase in fire prevention research in metal and nonmetal mines. Research was initiated to evaluate and develop improved detection and suppression systems for deep shaft metal and nonmetal mines, the use of fire-protective coatings on shaft liners, the use of inflatable stoppings in these mines to control ventilation, and the development of fire suppression systems for mobile mining equipment, both underground and on the surface. Figure 7 shows the devestating effects of a large mobile equipment fire.

Figure 7. A large surface vehicle fire

Research continued at a fast pace throughout the 1970's, concentrating on the detection, control, and extinguishment of mine fires. In the area of mine fire detection, spontaneous combustion studies were made to understand the low temperature oxidation mechanism for early detection. This also included the development of tube bundle systems for sampling worked-out areas, and the evaluation of various gas indices to understand the state of a mine fire. These indices are routinely used today at mine fires as guides for rescue and re-entry. The first generation of submicron smoke and metal oxide detectors were developed. Contract research evaluated the adequacy and equivalency of fire detection and suppression systems for belt entries. Research was also conducted in-house and through contracts to understand the spread of fire contaminants through the mine ventilation system and the effect of fire size and ventilation on contaminant spread. One of the products of this research was the MFIRE mine fire ventilation code, still in use today (Greuer 1977).

For the remainder of the decade, the Bureau's research program began to de-emphasize small-scale studies and shifted to large or full-scale in-mine investigations. The Bureau entered into a cooperative agreement with MESA with respect to development and evaluation of mining regulations. Under this agreement, the Bureau conducted evaluations of the Schedule 2G criteria for conveyor belt flammability and Schedule 30 criteria for flammability of hydraulic fluids, and evaluated the vulnerability of bulkheads to fires. A full-scale in-mine evaluation of a second generation CO monitoring system was also completed (Litton 1979).

1980's

Fire research in the 1980's continued on developing new or improved fire test standards for mine combustibles, such as plastic fluid containers, rigid and flexible ventilation ducting, and polyurethane sealants, based on large-scale experiments. In addition, a comprehensive program was completed to quantify the toxicity loads of mine combustibles (Egan 1990). In 1980, the Lake Lynn Laboratory (LLL), a state-of-the art mining research facility located near Uniontown, Pa, began operation (Triesbsch and Sapko 1990). In 1984, a fire gallery was constructed at the Lake Lynn Laboratory, which allowed full-scale flammability testing of mine conveyor belting. Figure 8 shows a full-scale conveyor belt flammability experiment in the fire gallery. These tests clearly demonstrated the inadequacy of the small-scale Federal acceptance test for fire-resistant belting and led to the development of a new laboratory-scale test method (Lazzara and Perzak 1989). Automatic sprinkler and dry chemical suppression systems in conveyor belt entries were evaluated in the fire gallery to determine the effect of ventilation on their effectiveness (Smith et al). The integrity of steel and concrete block stoppings, used to separate the airways carrying air to and from the working face, was evaluated in large-scale fire tests (Ng et al 1988). Spontaneous combustion research investigated variables that contribute to the self-heating process and developed a laboratory test method to predict the potential for spontaneous combustion (Smith and Lazzara 1987).

Figure 8. A conveyor belt fire experiment in fire gallery

Research continued on the development of rapid and reliable fire and product of combustion sensors. The Bureau patented and commercially licensed a sensitive smoke detector for underground mines (U. S. Patent 4,053,776). A prototype model of a diesel-discriminating smoke detector was developed and evaluated in mines. The location and placement of sensors is critical in the performance of a detection system. Mine studies were conducted to determine the effect of crosscuts, air velocity, and placement in the entry on detector response. Guidelines for spacing of carbon monoxide and smoke detectors in conveyor belt entries were published (Litton et al 1991). The Bureau also assisted MSHA in the establishment of regulations for metal and nonmetal mines. Research studies were completed on the flame propagation, rate of heat release, and products of combustion of timber-lined shaft fires. Deep shaft fire suppression systems were evaluated and in-mine validation of the MFIRE ventilation code for toxic fume spread was completed.

1990's

The fire research program of the 1990's was centered on the prevention, detection, and suppression of mine fires. The Bureau began a series of very successful Open Industry Briefings on Mine Fire Preparedness. These 2-1/2 day briefings were conducted at the Lake Lynn facility, and were tailored to mine safety and training personnel, rescue and fire brigade team members, and supervisors and shift foremen. Participants heard the latest in fire research from Bureau researchers and viewed large-scale demonstrations. The demonstrations included full-scale conveyor belt and ventilation tubing fires, the response of fire detection systems to small coal fires, and the extinguishing of liquid fuel fires using various fire-fighting equipment (Conti 1994).

In 1995, the Bureau developed a computer program to assess the spontaneous combustion risk of an underground mining operation, based on the coal's spontaneous combustion potential and the geologic and mining conditions encountered in the mining of the coal, and the mining practices employed (Smith et al 1995). This program is used by mine operators to determine the best in-mine ventilation methods to control spontaneous combustion. Detection studies focused on strategies for sensor deployment and understanding the effect of a fire on the ventilation patterns and smoke rollback. Research continued on the improvement of sensor technologies, particularly the development of the diesel-discriminating detector. Studies were also conducted to determine the feasibility of a remote optical methane detector.

THE MOVE TO NIOSH

In September 1995, Congress recommended the closure of the Bureau of Mines. Through the efforts of many stakeholders, the function of mining health and safety was retained by the government, first under the Department of Energy. In 1996, the Office for Mine Safety and Health (OMSH) was established under the National Institute for Occupational Safety and Health (NIOSH). The OMSH immediately began the formulation of a Mining Strategic Plan to guide health and safety research activities, consistent with the needs of stakeholders and the mission outlined by the U. S. Congress. The OMSH relied heavily on stakeholder insight and empirical statistical data to establish the most efficient and effective Strategic Plan.

The plan set goals in the area of fire prevention to reduce fires in underground coal mines associated with conveyors and haulage systems, fires associated with flame cutting and welding, and the establishment of performance standards and location strategies for mine fire detection systems. Research was completed to evaluate the application of new and improved fire suppression systems, such as water mist suppression systems, to protect underground mine haulage ways and stationary equipment, such as compressors and electrical substations, and diesel fuel storage areas (Smith and Lazzara 1998). Methods for the remote sealing and remote suppression of mine fires were developed (Trevits et al 2007). Because of the issue of using belt air at the working face, experiments were completed to determine the effect of air velocity on fire suppression system performance (Rowland et al 2009). The root causes of flame cutting and welding fires in both underground and surface mining were identified and guidelines for safe flame cutting and welding operations were developed (Monaghan et al 2006). The goal of reducing noise exposure in mining led to an increased use of noise abatement materials in both aboveground and underground equipment cabs. The flammability hazards of different types of noise materials were identified and guidelines for use were published (Litton et al 2003). Research was also conducted to determine the intrinsic causes of large surface vehicle and equipment fires and new or improved fire protection systems for these vehicles and equipment were developed (DeRosa and Litton 2007). A “smart” sensor system utilizing neural network methodology was developed. The system has the capability to detect the fire, discriminate the fire combustible source in a diesel background, and provide a mine fire location strategy in an underground mine. This system was successfully demonstrated at an underground coal mining operation (Franks et al 2008). The sensor installation at the mine is shown in figure 9.

Figure 9. “Smart” sensor detection system installed at mine

THE MINER ACT

On January 19, 2006 an underground mine conveyor belt fire occurred at a West Virginia coal mine, fatally injuring two miners. This accident, along with two other mine tragedies in 2006, which resulted in 17 additional fatalities, led to The Mine Improvement and New Emergency Response Act of 2006 (MINER ACT). This legislation amended the Mine Safety Health Administration Act of 1977 to improve the safety of the mines and mining. Section 11 of the Miner Act required that a Technical Study Panel (The Panel) be formed to provide recommendations on the use of belt air and new technology that may be available for increasing fire safety. These recommendations include the use of recent technological advances applied to the current state of the art for fire-resistant conveyor belt materials, belt fire suppression systems, atmospheric monitoring systems, and escapeway integrity to improve miner safety.

In 2007, the fire research program was re-evaluated and re-directed to address the recommendations of the Act. A project was started to reduce the hazards of underground coal mine fires by applying recent technological advances in the areas of fire-resistant conveyor belt materials, belt fire suppression systems, atmospheric monitoring systems, and computer codes for predicting and assessing in real-time the impact of fire on the mine ventilation system and the spread of fire contaminants throughout the mine. The project includes tasks to address some of the major issues concerning fires in underground coal mines; flammability of conveyor belts, detection, suppression systems, fire modeling of conveyor belts, fire modeling of contaminant spread, and fire risk assessment. This project is currently ongoing. Research is being conducted to compare the results of full-scale conveyor belt flammability tests to the recently developed reliable small-scale test to determine the effect of high ventilation velocities on the flammability hazards of conveyor belts. Research is planned to define sensor location and response time in conveyor belt entries with wider belts and high air velocities to ensure adequate warning time to mine personnel. Experiments are being conducted to evaluate novel suppression systems currently available in the United States and in other countries in full-scale tests to determine if improvements can be made, such as changes in spacing of sprinklers or dry powder nozzles, to improve their effectiveness. Mine Fire Risk Assessment software aids are being developed utilizing a set of potential hazards that must be considered. The MFIRE ventilation code is undergoing modernization to increase its capabilities for smoke management during a mine fire emergency.

Spontaneous combustion continues to pose a hazard for U.S. underground coal mines, particularly in western mines where the coal is generally of lower rank. The risk of an explosion ignited by a spontaneous combustion fire is also present in those mines with appreciable levels of accumulated methane. In fact, three of the mine fires from the reported period 1990-1999 resulted in subsequent methane explosions. A new project is using CFD modeling technique to develop new methods to prevent, detect, control and suppress the spontaneous heating in mines (Yuan and Smith 2007).

SUMMARY

Mine fire research has been an integral part of the Bureau of Mines and NIOSH mission for 100 years. There have been many major advances in mine fire safety that have led to a significant decrease in the occurrence and injury and fatality rates over this time. However, the potential for disaster remains, so we must not rest on our laurels. With the use of new technology to mine coal and other minerals, and the mining of deeper and gassier mines, the hazards will continue to evolve. Our research must also continue to evolve to meet these challenges to continue to provide the safest and healthiest workplaces for our miners.

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