Underground Coal Mine Disasters 1900 - 2010:
Events, Responses, and a Look to the Future

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ABSTRACT: *This paper captures almost 110 years of history of underground coal mine disasters in the United States. The deadly disasters of the first ten years of the twentieth century led to the U.S. Congress founding the U.S. Bureau of Mines (USBM) in 1910. The authors examine the changing trends in mine disasters including the frequency of fatalities, causal types, the responses to those disasters and most importantly, the growing body of research on human behavior in mine emergencies. Emphasis is on the future - integrating the research on human behavior in disasters into the mining industry. This research includes the integration of the judgment decision-making process, communication, leadership in escape, expectations training, incident command center issues including fatigue, shifts and leadership, plus issues concerning the introduction of refuge chambers into U.S. mines. The authors suggest that a key factor in meeting the goal of increasing successful mine escape and rescue while decreasing fatalities and injuries lies in the field of social-psychological research and human behavior interventions.*

INTRODUCTION

Mine disasters have been a focal point among mine operators, safety and health personnel, and miners, as well as mine safety and health researchers in the United States for decades. Hundreds of disasters, resulting in thousands of mine worker deaths, have occurred in mines since 1900.

Because most of these catastrophes have occurred in underground coal mines, the authors have chosen to focus on these disasters in this paper. The authors examine and discuss the history of coal mine disasters in the U.S. with emphasis on changing trends in disasters, responses to the disasters, the growing body of research on human behavior in mine emergencies, and implications for future integration of research on human behavior into the mining industry.

The Mine Safety and Health Administration (MSHA) classifies disasters by number of fatalities and by cause. MSHA defines a "disaster" as an incident with five or more fatalities. In this paper, the authors do not differentiate “incident” from “disaster”, and discuss incidents with too few fatalities to be classified as "disasters" by MSHA. Causes are grouped into six categories: 1) explosion; 2) fire; 3) haulage (transportation of personnel, materials, or equipment); 4) ground fall/bump (fall of roof rock or an outward, violent burst of a pillar); 5) inundation (the sudden inrush of water or toxic gases from old workings); and 6) other (MSHA 2006a).

From 1900–2006, 11,606 underground coal mine workers died in 513 U.S. underground coal mining disasters, with most disasters resulting from explosions (Kowalski-Trakofler, et al.,2009a). In 2007, 9 additional workers died in the Crandall Canyon disaster (Gates, et al. 2007a), bringing the total to 11,615 miners killed in 514 disasters. Table 1 summarizes the number of disasters by category and the related number of fatalities for the period.

Table 1. Number of underground coal mine worker fatalities by type of disaster, 1900 through 2008

Type incident	Number of Events	Number of Fatalities
Explosion	420	10,390
Fire	35	727
Haulage	21	145
Ground fall/Bump	14	92
Inundation	7	62
Other	17	199

The major coal mine disasters are presented within three time periods: *1900 – 1909*, preceding the founding of the Bureau of Mines; *1910 – 1969*, a period of significant decrease in underground coal mine disasters; and *1970 – present*, a period when human behavior and psycho-social factors came into play. Industry and congressional responses to these events are also presented in these timeframes.

THE EVENTS: MAJOR COAL MINE DISASTERS

The period 1900 through 1909

The period 1900 through 1909 was the deadliest decade in U.S. underground coal mining, and led to the legislation that founded the Bureau of Mines with the express mandate of reducing fatalities in the mining industry. From 1900 through 1909, 3,660 miners perished in a total of 133 mine disasters. Sixteen major mine disasters during this time period killed 2,070 miners. These 16 events are summarized in Table 2.

Table 2. Major U.S. underground coal mine disasters, 1900-1909

Year	Mine	Type Disaster	No. Killed
1902	Fraterville	Explosion	184
1902	Rolling Mill	Explosion	112
1903	Hanna No. 1	Explosion	169
1904	Harwick	Explosion	117
1905	Virginia City	Explosion	112
1907	Stuart	Explosion	84
1907*	Naomi	Explosion	34
1907*	Monongah Nos. 6 & 8	Explosion	362
1907*	Yolande	Explosion	57
1907*	Darr	Explosion	239
1907*	Bernal	Explosion	11
1908	Hanna No. 1	Explosion	59
1908	Rachel and Agnes	Explosion	154
1908	Lick Branch	Explosion	50
1909	Lick Branch	Explosion	67
1909	Cherry	Fire	259

*Occurred in December, 1907

December 1907, known as “Bloody December”, is the deadliest on record for the U.S. underground coal mining industry. That month 703 miners died in 5 mine explosions.

The Monongah Nos. 6 & 8 disaster, the Darr disaster, and the Cherry disaster remain 3 of the deadliest events in U.S. coal mines.

The period 1910 through 1969

After the founding of the Bureau of Mines, a number of major events were still to come. Many of the events lead to changes in U.S. mine safety and health regulations. Overall, 1910-1969 was a period of significant decrease in disasters.

Stag Canyon No. 2 Mine - 1913

An October 1913 explosion rocked the Stag Canyon No. 2 mine in New Mexico, killing 263 workers in the mine. Fourteen miners escaped from an unaffected part of the mine; 9 others were rescued from the bottom of the air shaft. The explosion was caused by detonating an overcharged shot in a dusty pillar section (MSHA, 1998a).

Eccles Nos. 5 and 6 Mines - 1914

A methane explosion occurred in April 1914 at the Eccles Nos. 5 and 6 mines in West Virginia. There were 246 miners working when the explosion occurred. All 172 miners working in the No. 5 Mine were killed. Afterdamp killed 8 miners in the No. 6 mine, working in the coal seam above. Sixty-six miners escaped from the No. 6 mine (Ibid).

Castle Gate No. 2 Mine - 1924

A series of three explosions struck the Castle Gate No. 2 mine in Colorado in March 1924. The disaster claimed the lives of 172 workers. The initial explosion occurred when a mine examiner attempted to relight his key-locked safety lamp from his carbide cap lamp and ignited methane (Ibid).

Mather No. 1 Mine - 1928

An explosion in May 1928 at the Mather No. 1 mine in Pennsylvania killed 195 of the 279 workers underground. Methane accumulated in a working section, possibly caused by an open mandoor. The gas was ignited by an arc from a battery locomotive working in the area (Ibid).

After the Mather mine explosion, there were no major mine disasters for 12 years, until 226 miners died in three major disasters between January and July 1940. Two other major disasters, in 1942 and 1943, killed 130 miners (Ibid).

Centralia Mine - 1947

An explosion in the Centralia No. 5 mine in Illinois killed 111 miners. Eight miners were rescued and 24 managed to escape after the explosion. The disaster is believed to have been caused by either an insufficiently charged shot or a blown-out shot stemmed with coal dust (Ibid).

Orient No. 2 Mine - 1951

An explosion in December 1951 at the Orient No. 2 mine in Illinois killed 119 of the 256 miners working underground. A main ventilation door was left open, relieving the ventilation pressure on old abandoned panels. It is believed methane came out of abandoned panels and traveled to an active section where it ignited, possibly due to an arc from electrical equipment (Ibid).

Farmington No. 9 - 1968

The frequency and severity of underground coal mine disasters continued to decline in the 1950s and 1960s. Many mine safety practitioners believed the day of major disasters had come to an end, until a major explosion tore through the Farmington No. 9 mine in West Virginia on November 20, 1968. At the time of the explosion, 99 miners were working underground; only 21 managed to escape. With no hope of finding survivors, the mine was sealed on November 30, 1968 (MSHA 1989). The mine was recovered and between September 1969 and April 1978, the bodies of 59 victims were removed. The mine was permanently sealed in November 1978, leaving 19 victims entombed. The cause of the explosion was never determined. However, the event would have far reaching effects that would forever shape U.S. mine safety and health (MSHA 1998a).

The period 1970 through 2008

While the frequency and severity of underground coal mining disasters along with the number of miner deaths decreased substantially during 1970–2005, several significant disasters did occur that had further impact on mine safety and health in the U.S. Before 2005, the total number of mining disasters had decreased from a high of 20 in 1909 to an average of one every 4 years during 1985–2005 (Kowalski-Trakofler, et al. 2009a). However in 2006, disasters at the Sago mine in West Virginia and the Darby mine in Kentucky claimed a total of 17 lives. The 2007 Crandall Canyon disaster killed 9 workers. No mine disasters occurred in 2008.

Scotia Mine - 1976

In March 1976, two explosions occurred on separate days at the Scotia Mine in Kentucky. The first occurred on March 9, killing 15 of the 116 miners working underground. The second explosion took place on March 11, during recovery operations. It killed 11 of 13 workers underground, including several inspectors. Investigators believed the first explosion occurred when an accumulation of methane in a track entry was ignited by arcing created in the controller of a locomotive. The second explosion is also believed to have occurred when methane was ignited by an arc from electrical equipment (MSHA 1998b).

Following the Scotia mine disaster, a handful of other disasters occurred in the U.S. Table 3 summarizes these events.

Table 3. Underground coal mine disasters, 1977-1999			
Year	**Mine**	**Type Disaster**	**No. Killed**
1977	Porter Tunnel	Inundation	9
1980	Ferrell No. 17	Explosion	5
1981	Dutch Creek No. 1	Explosion	15
1981	Adkins Coal No. 11	Explosion	8
1981	Grundy Mining No. 21	Explosion	13
1982	RFH Coal No. 1	Explosion	7
1983	Clinchfield No. 1	Explosion	8
1984	Wilberg	Fire	27
1986	Loveridge No. 22	Other*	5
1989	William Station	Explosion	10
1992	South Mountain	Explosion	8

*Stock pile collapse

After the South Mountain mine explosion in 1992, there were no major coal mine disasters until 2001.

Jim Walter Resources No.5 Mine - 2001

In September 2001, two separate mine explosions occurred at the Jim Walter Resources No. 5 Mine in Alabama, killing 13 miners. The first explosion occurred after a roof fall at a scoop battery charging station. The fall damaged a scoop battery and ventilation controls, and an arc flash from the damaged scoop battery ignited methane. The explosion damaged critical ventilation controls and injured four miners who were working in the affected section. Three of the miners escaped while the fourth was left behind because of the seriousness of his injuries.

The second explosion occurred as 12 miners made their way to rescue the miner left behind. This explosion was most likely caused when a signal light system ignited methane in the track entry. At least 12 miners were killed by the second explosion. It is not known if the 13th miner, the one left behind after the first explosion, died from his initial injuries or as a result of the second explosion (McKinney, et al. 2002).

Sago Mine - 2006

An explosion in January 2006 at the Sago Mine in West Virginia killed 12 miners. A crew of 12 miners entered the mine shortly before the explosion, and proceeded toward their section. A second crew of 16 miners entered the mine shortly after the first crew and traveled toward their section. After the first crew reached their section, an underground methane explosion occurred approximately two miles from the entrance, near a worked out, sealed area of the mine. The explosion instantly killed one miner, a mine examiner working alone in the vicinity of the blast.

After the explosion, the 12 miners of the first crew were unable to escape because of smoke and dust. The crew returned to their section, barricaded, and awaited rescue. Eleven of the 12 died from carbon monoxide before rescuers reached them. The second crew was outby the explosion and was able to escape the mine. Investigators believe energy from a lightening strike was transferred onto an abandoned length of damaged electrical cable in the sealed area, igniting methane that accumulated in the abandoned workings (Gates, et al. 2007b).

Alma No. 1 Mine - 2006

Two miners died in a mine fire at the Alma No. 1 Mine in West Virginia in January 2006. A total of twenty-nine miners were working underground when the fire broke out at the longwall section belt take-up. Because of the ventilation arrangement, the longwall crew was able to evacuate the section in fresh air through a set of cut-through entries that brought air into the longwall panel from the mains. Another crew, working inby the fire, proceeded to evacuate. Partway out of the mine, this crew abandoned their mantrip because of heavy smoke. For unknown reasons, two miners from this crew became separated from the rest of the group and perished. The bodies of the two missing miners were found two days after the fire began (Murray, et al. 2007).

Darby No.1 Mine Explosion - 2006

In May 2006, an explosion occurred at Darby No.1 Mine in Kentucky, killing 5 miners. At the end of the afternoon shift, a group of 5 miners headed outside on the mantrip. Two afternoon shift miners stayed behind to cut roof straps near a ventilation seal in the return airway. At the same time, the midnight shift crew was entering the mine. Shortly after the afternoon shift crew reached the outside, an explosion occurred in the mine. The two miners performing the cutting work died in the explosion, and three miners from the entering midnight shift crew died while trying to escape. One miner survived and was able to travel part of the way towards the mine entrance wearing his self-contained self-rescuer (SCSR). He was later rescued. The explosion was the result of improper construction of the mine seals and inappropriate use of cutting/welding equipment in the return airways (Light, et al. 2007).

Crandall Canyon - 2007

The most recent mining disaster in the United States occurred in August 2007, when a major coal bump or bounce occurred on the Main West pillar section at Crandall Canyon mine, trapping and killing 6 miners. Underground rescue and recovery work began immediately but was suspended 10 days later, when a second major bump/bounce killed 3 rescue workers. All rescue/recovery work was suspended on August 31, 2007. In all, 9 miners died as a result of the disaster (Gates, et al. 2007a).

THE RESPONSE: SYNOPSIS OF PERTINENT MINE SAFETY LEGISLATION

For years mine operators, federal and state mine safety agencies, and researchers have looked at numerous aspects of mine disasters. The most intense efforts in this arena have occurred following major mine emergency incidents. The response to these disasters have taken a variety of forms, with the most impactful being legislation adopted at the federal and/or state level. As Nieto and Duerksen (2008) point out, this legislative response is cyclical with each event. Pennsylvania adopted the first significant mine safety legislation in 1870. The first federal mine safety regulations were passed by Congress in 1891 (MSHA, 1998a).

U.S. Bureau of Mines Established

As mentioned earlier, 16 significant mine disasters occurred in the U.S. from 1900 through 1909. These events, including five disasters in December 1907, caused citizens and lawmakers to focus on coal mining and the dangers it presented to workers. After intense public pressure, Congress passed Public Law 61-79 in 1910. This law created the United States Bureau of Mines, an agency whose primary mission was mine safety research and investigation (MSHA, 1998a). The goal was to mitigate underground coal mine disasters through application of research.

Public Law 77-49 - *1941*

After the establishment of the Bureau of Mines, additional coal mine disasters continued to occur. These included the disasters at the Stag Canyon No. 2 mine, 1913; Eccles Nos. 5 and 6 mines, 1914; Castle Gate, 1924; and Mather mine, 1928. As mentioned previously, several additional major disasters occurred in the early 1940s.

These disasters, coupled with the overall high death rate among underground coal miners, led Congress to pass Public Law 77-49 in 1941. This law gave Federal mine inspectors right of entry to carry out annual mine safety inspections and investigations.

Public Law 80-326 - *1947*

The March 1947 Centralia mine explosion led Congress to enact Public Law 82-326. This new law, which expired one year after enactment, authorized the crafting of the first Code of Federal Regulations for bituminous and lignite coal mine safety. However, there were no provisions in the law for enforcement of the regulations (Ibid).

Public Law 82-522 - *1952*

The December 1951 Orient mine explosion, along with fallout from the 1947 Centralia tragedy prompted Congress to pass Public Law 82-522, the 1952 Federal Coal Mine Safety Act (1952 Act). The law emphasized prevention of major mine explosions. It mandated regular annual inspections of mines and provided the Bureau of Mines with limited enforcement power. Although anthracite coal mines were covered by the new law, surface mines and all mines employing fewer than 15 workers were exempt (Ibid).

Public Law 89-376 - *1966*

Despite strengthened safety regulations, a number of disasters occurred following the passage of the 1952 Act. In 1966, Congress passed Public Law 89-376, extending provisions of the 1952 Act to all underground coal mines. The new law permitted mine inspectors to issue withdrawal orders in the event of an unwarrantable failure on the part of a mine operator to comply with regulations (Ibid). Withdrawal orders require operators to withdraw all workers from the affected area until the hazard has been mitigated.

Public Law 91-173 - *1969*

The provisions of the 1952 Act, strengthened in 1966, still did not stop major disasters. The U.S. underground coal industry was rocked by the 1968 Farmington disaster. The Farmington event led to Public Law 91-173, the Federal Coal Mine Health and Safety Act of 1969 (1969 Act). This new law was the most sweeping and comprehensive mine safety legislation ever in the U.S. and forever changed the face of coal mine health and safety. The law included both surface and underground coal mines, and mandated two annual inspections at surface mines and four per year for underground mines. Enforcement powers were increased, safety standards strengthened, and new health standards adopted. The law established fines for violations and criminal penalties for willful violations of the law and set forth basic safety and health training requirements (Ibid).

Public Law 95-164 - *1977*

After the 1976 Scotia mine disaster, Congress enacted Public Law 95-164, the Federal Mine Safety and Health Act in 1977. This legislation moved mine safety and health enforcement to the Mine Safety and Health Administration and placed the agency under the Department of Labor. The new law combined coal and metal/nonmetal mine safety and health regulations and contained enforcement provisions similar to those of the 1969 Act. This law strengthened miners' rights, established the Federal Mine Safety and Health Review Commission, and strengthened training requirements first set forth in the 1969 act (Ibid).

Public Law 109-236 - *2006*

Following the 1977 Federal Mine Safety and Health Act, only a handful of additional mine disasters occurred in the U.S. However, in the first five months of 2006, the Sago and Darby mine explosions and the Alma No. 1 fire all occurred, and brought mine safety and health to the forefront again. Following these disasters, Congress passed Public Law 109-236, the Mine Improvement and New Emergency Response Act of 2006 (MINER Act). The MINER Act contained provisions for improving safety, health, preparedness, and emergency response at U.S. mines. Among other elements, the MINER Act requires operators to develop and maintain emergency preparedness and response plans to reduce delay and improve response quality. The Act also requires mine operators to provide additional SCSRs, escapeway lifelines, wireless two-way communication and tracking, and refuge alternatives. It also mandates care for the families of trapped miners (MINER Act 2006).

BEHAVIORAL RESEARCH IN MINE DISASTERS

Until relatively recently, human behavior in mine emergencies was largely ignored as an area of research. Following many major mine disasters, legislation was enacted to improve mine safety and health, focusing on prevention through research interventions, mandated inspections, regulatory compliance, and eventually safety and health training. However, until NIOSH embarked in research aimed at assessing miners' behavior in mine emergencies in the late 1980's, the effect of human behavior on the outcome of major events remained unstudied. Since that time, such behavioral research has proved to have far-reaching implications, especially with respect to training for mine escape or disaster management. In their report, the National Mining Association's Mine Safety Technology and Training Commission (2006) reported on the importance of behavior research in mine emergency response and the need for continued efforts in this area.

Worker Behavior in Mine Emergencies

After a mine emergency occurs, the event is investigated by both the state mining agency and MSHA. These investigations focus on the elements of the incidents in an attempt to identify root causes, actions taken, and to recommend ways to prevent such events in the future. Before 1988, no one had studied mine emergency events from the human behavior perspective.

From 1988 through 1990, NIOSH researchers interviewed 48 miners who escaped three different mine fires. Miners discussed their actions and thoughts from the time they first became aware that there might be a problem in their mine until they reached safety. The interviews resulted in more than 2,000 pages of data. In analyzing miners' testimony, researchers discovered an array of decision variables related to various aspects of individual and group behavior. Researchers constructed a model of workers' behavior escaping a mine fire (Vaught, et al. 2000). These human behavior elements play an important role in miners' ability to respond to a mine emergency.

Judgment and Decision Making

There is limited literature on the process of judgment and decision-making under stress (Kowalski-Trakofler, et al. 2003). The study by Vaught, et al. (2000) was the first one to examine the judgment and decision making process within the context of a mine emergency. Based on analysis of miners' testimony, researchers discovered that the miners underwent a complex decision making process as they escaped. The researchers were able to construct a model of the judgment and decision making process (Figure 1).

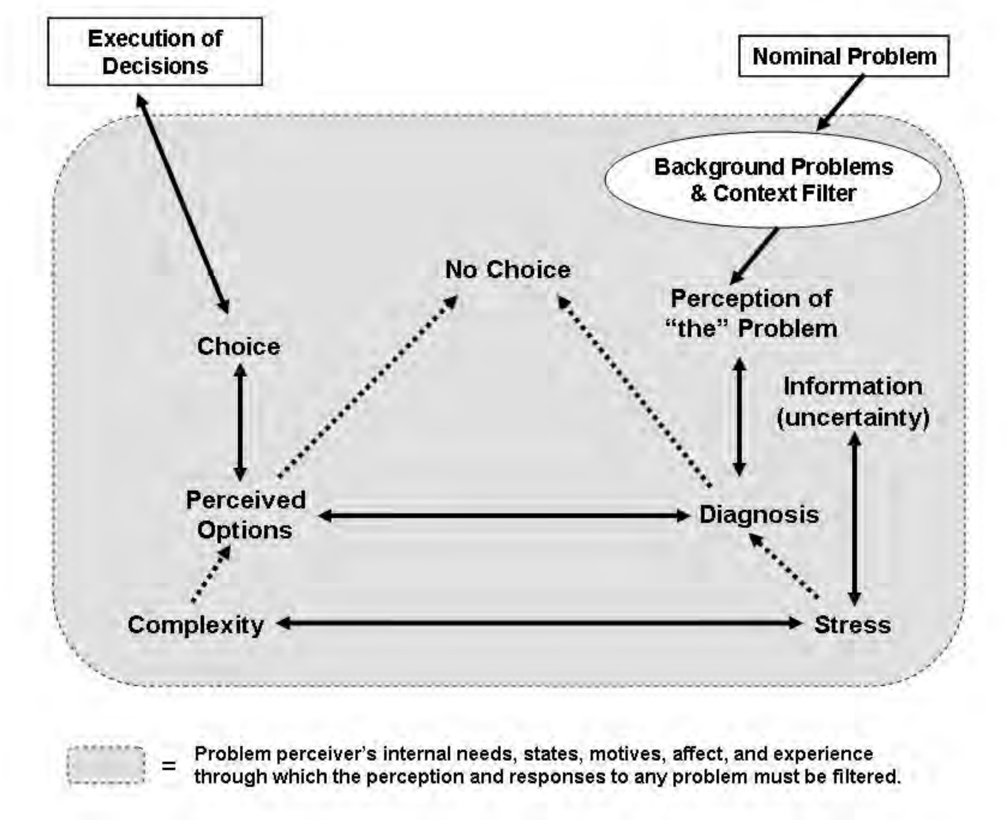

Figure 1. Model of judgment and decision making

Escaping miners go through a multi-step process in judgment and decision making. This process is ongoing and continues from when they first perceive there is a problem until they reach safety. Initially, miners are presented with the nominal problem. In the case of the 48 miners interviewed, this was a mine fire. As miners begin perceiving the problem, background problems and contextual issues factor in. Background problems include information such as knowledge of the fire location or the smell of smoke. Contextual issues include miners initially framing the problem as a normally occurring event, such as smelling smoke from bonds being welded at rail joints.

Once the miners perceived the problem, they entered a diagnosis or analysis phase. Stress from a variety of sources, including information uncertainty, affected their ability to effectively analyze the situation. After analyzing the situation, miners assessed options available for responding to the circumstances. Then, they selected an option and executed their decision. In some instances, miners made choices and executed decisions only to find that they made the wrong choice. They would then be required to re-evaluate the situation, perhaps through further diagnosis, and then make new decisions about courses of action. This judgment and decision making process continued throughout the entire escape.

Researchers identified several important points about judgment and decision making. First, miners tended not to perceive the problem accurately at first. Often they tried to place the problem within the context of normal activities, rather than as an emergency situation. Second, the diagnosis made by escapees was affected by the nature of the warning message they received. Third, miners' perceived options and choices were impacted most by their overall knowledge of the mine and the quality of information available.

Researchers discovered other factors affecting judgment and decision making in a mine emergency such as a fire. These include wayfinding and cognitive (mental) mapping, which are two important components in escape; leadership, which played a significant role in escape from the three mine fires (Kowalski, et al. 1994); fire warning and information uncertainty; and group dynamics (Vaught, et al., 2000).

Leadership

Researchers investigated the emergence of leadership in escape from the three underground mine fires (Kowalski, et al. 1994). Attributes of leaders who facilitated escapes were identified and compared, as were instances of lack of leadership. The structure of the group leadership before the crisis was compared with the reality of the leadership during the crisis. The day-to-day leader was not necessarily the one who lead the miners out of the burning mine. Some groups experienced leadership breakdown during their escape, while others witnessed the emergence of leadership.

Researchers identified six consensus characteristics of leaders. The leaders (1) were aware and knowledgeable, (2) were decisive, yet flexible, (3) were open to input from others, (4) had a calming influence and gained followers' confidence, (5) were logical decision-makers, and (6) and allowed leadership to develop naturally.

Refuge Chambers

After the incidents of 2006, attention turned to the use of refuge chambers in underground coal mines. The 2006 MINER Act mandated that every coal mine in the country must have such chambers in place by 2009. The use of these chambers has raised a number of psycho-social questions beginning with when, and if, to go into a chamber. Escape is always the first option. NIOSH initiated a project to "develop engineering guidelines associated with the location, construction, and general application of various refuge alternatives" (Ounanian 2007, p.1). The first phase of the project evaluated the impact that refuge chambers could have made in the outcome in coal mine explosions, fire emergencies, and mine inundations in which fatalities occurred from 1970 through 2006. The potential effect of refuge chambers on both survivors and fatalities was estimated. Thirty-eight disasters were studied and the results of the event tree analysis indicated that the availability of "refuge stations (chambers) would have had a positive impact on the outcomes of 12 disasters or 32%. The total number of miners that would have been positively impacted was 83 (19%) of the 429 underground and impacted (miners) by these accidents. A total of 74 (29%) of the 252 fatalities would have been positively impacted and potentially would have survived the accident. These numbers are based on the assumptions that were made during the analysis of the mine disaster reports. These assumptions are conservative and based on sound understanding of coal mining environments, operations and procedures." (Ounanian 2007, p.3). The report also specified that psychological factors would strongly influence miners when using a refuge chamber.

At the time of the 2006 incidents, refuge chambers were not available. If they had been available, they may have saved the lives of 12 of the Sago miners and three of the Kentucky Darby miners (Ounanian 2007). Recently, NIOSH has developed and tested two training products to help miners understand and make decisions about refuge chambers. The first helps miners make a decision about whether to enter a refuge chamber in an emergency, and the second provides expectations training in the form of information about what behaviors emotions and physical reactions a miner might expect in a chamber over a period of time (Vaught, et al. 2009; Margolis, et al. 2009).

Command Center Issues

Human behavior issues in mine emergency command centers have been assessed to some extent, although more research is needed. The behavioral sciences can contribute to knowledge of productive command center behaviors such as leadership, limiting fatigue, decision-making under stress, setting appropriate shifts, and maintaining nutrition for command center and rescue personnel. Additional topics that could be addressed include command center organization, data overload, and integration of psychosocial support.

THE FUTURE: BEHAVIORAL HEATH ASPECTS OF MINE DISASTER

In the 21st century, the U.S. mining industry can look back over 100 plus years of disaster history and note several trends that stand out. Initially, the industry focused on controlling fires and explosions in underground coal mines to mitigate disasters. Gradually, researchers expanded their inquiries to broader engineering control solutions for prevention. It is only in the past 25 years that research has slowly moved into studying human behavior in mine safety and health, beginning with disaster behavior in escape and rescue.

Psychological issues can play a major part in a successful escape. An individual's state-of-mind affects his/her cognition, emotional, behavioral, and physical state. Miners escaping from an underground coal mine, in fear for their lives, suffer considerable stress and the resultant symptoms. Decision makers in the command center are also subject to stress.

It is normal for miners, rescue personnel, and command center leaders to experience these reactions during a mine emergency. The immediate reactions are commonly referred to as the *fight or flight response*. This is the survival instinct that all individuals are born with; it prepares the individual to fight or to run in order to survive. In a mine emergency, this response prepares the body to escape. Psychologists refer to an incident like an emergency escape from a mine as a "traumatic incident" and research has documented some of the normal human reactions to traumatic incidents, both short term and long term. Understanding these normal reactions can facilitate orderly escape behavior and good judgment and decision-making.

Short-term responses to a traumatic incident usually include strong reactions, especially emotional reactions. These emotions are normal reactions to an extra-ordinary situation. Individuals are different and report some or none of the following symptoms: rapid heartbeat, dry mouth, sweaty palms, increased anxiety, fear, sweating profusely, feeling confused, feeling overwhelmed, shallow breathing, nausea, disorientation and poor problem solving. Longer term symptoms might include a continuation of some of the more immediate responses plus nonspecific aches and pains, nightmares, disorientation, poor concentration, guilt, irritability, depression, sense of failure, intense anger, withdrawal, change in sexual functioning, or change in eating and alcohol habits. A few larger mines in the U.S. have contracted with disaster trained mental health professionals to assist with operation planning and emergency response. NIOSH has found in focus groups that stakeholders are increasingly aware of the importance of incorporating psychological responses in training and after-event support (Kowalski et al. 2009b, in press).

Psychologically, preparation is the most important predictor of reactions in emergencies. Regular drills, equipment testing and donning, and expectations training can help to mitigate symptoms. Few programs in the mining industry address expectations training from a human behavior perspective. One good example of sound expectations training was developed after Sago. NIOSH researchers conducted a study investigating the human response issues related to wearing an SCSR, with the goal of developing training for miners on what they could expect from their units during an escape. Subjects included miners who had experience wearing SCSRs, manufacturers, and researchers. Results identified nine key areas of concern: (1) starting the unit, (2) unit heat, (3) induction of coughing, (4) unit taste, (5) difficulty in breathing while wearing the unit, (6) quality of the air supplied, (7) nose clips, (8) goggles, and (9) the behavior of the breathing bag (Kowalski-Trakofler, et al. 2008). These findings resulted in a training component published in MSHA's SCSR expectations training module (MSHA 2006b).

CONCLUSION

The authors presented the major coal mine disasters within three time periods: 1900 – 1909 which preceded the founding of the U.S. Bureau of Mines, 1910 – 1969, a period of significant decrease in fires and explosions in underground coal mines, and 1970 – present, a period when the importance of human behavior and psycho-social factors were recognized. It is only recently in the history of mine disasters that behavioral health, psychology, and the behavioral sciences in general have impacted mine safety and health. The authors suggest that 2010 and beyond could be the era of the integration of aspects of human behavior with the technical expertise important to miner safety and health, especially in escape and rescue.

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