RESPONDERS TO UNDERGROUND MINE FIRES

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ABSTRACT

Fire is a major concern for those who work in underground mines. A mine fire can occur at anytime and often results in a partial or total evacuation of mine personnel and could result in the loss of lives. Therefore, having a workforce that is well trained to prevent, detect, and fight a fire is important. This paper focuses on responders' preparedness for fire. Responders in this context are considered the entire workforce and are categorized as first, second, and sustained responders and evacuating miners. Quality training enhances ones awareness of mine fire hazards and promotes self-confidence in combating fires and responding to emergencies. Early warning systems and other escapeway aids such as a through-the-earth signaling and communication system, lasers and strobe lights are also addressed. The technological advancements that have been made can improve the state-of-preparedness for responders to underground emergencies and increase the chances of survival for escaping personnel.

INTRODUCTION

Fires are still too common an occurrence in the mining industry. Mine Safety and Health Administration (MSHA) statistics[1] indicate that 137 fires (fires reported to MSHA) occurred in underground coal and metal/nonmetal mines from 1991 to 2000 in the United States, resulting in 2 fatalities and 34 injuries (these statistics also include the Willow Creek Mine fire and explosion). A significantly higher number of unreportable fires are believed to have occurred. Table 1 depicts the various categories of 76 underground coal mine fires and 61 underground metal/nonmetal mine fires from1991 to 2000. As seen from the table, friction fires are the most common category of underground coal mine fires, followed by other and mobile equipment. In underground metal/nonmetal mines, mobile equipment fires are the leading category of fires, following by cutting and welding and the other.

Table 1. Categories of Mine Fires.

Coal		Metal/Nonmetal	
Categories	**Pct**	**Categories**	**Pct**
Electrical	14	Electrical	10
Friction	24	Friction	5
Mobile Equipment	15	Mobile Equipment	46
Spontaneous Combustion	12	Spontaneous Combustion	2
Cutting and Welding	14	Cutting and Welding	16
Other	21	Other	21

Source: MSHA Accident Reports 1991 - 2000

Fire is a major concern for those that work

[1]Mine fire statistics were obtained from files maintained at MSHA's Denver Safety and Health Technology Center, Injury and Employment Information Branch, Denver, CO.

underground. A fire occurred during coal production on November 25, 1998, at the Cyprus Plateau Mining Corporation's Willow Creek underground mine near Price, Utah. Forty-five miners evacuated. The mine was sealed and inert gas injected into the fire area. The mine reopened and twenty months later, on July 31, 2000, two miners lost their lives and eight miners sustained injuries due to a fire and explosion. A more recent fire occurred on February 8, 2001, at the Homestake Gold Mine, Lead, South Dakota. Thirty-seven miners evacuated. Rescue teams mustered and discovered the fire in an old timber stope (inactive area) between the 1,067-m and 1,113-m levels. Water was used to flood the affected area. Historically, mine fires have caused fatalities, injuries, and economic losses totaling hundreds of millions of dollars. One of the goals of the National Institute for Occupational Safety and Health's (NIOSH) Pittsburgh Research Laboratory (PRL) is to enhance the safety of the mine worker by preventing disasters caused by fires and explosions.

The remote nature of underground mining requires workers, at all positions within the organization, to maintain higher skill levels in emergency response compared with workers in many other industries. Traditional work organizations can, in greater part, rely on professional, full-time, expert community services and specialists to assist in the response to fire, rescue, and medical emergencies. For example, smaller cities and towns have volunteer fire departments that are highly capable. The issue of measuring fire preparedness for the individual mine site is critical for predicting the response (including elements of evacuation and fire fighting) in case of an underground fire. What does it mean to be prepared to deal with fire in an underground mine?

A mine fire can occur at anytime and often results in a partial or total evacuation of mine personnel. Therefore, having a workforce that is well trained to prevent, detect, and fight a fire is important. It is also paramount for miners to maintain and know their escape routes. However, a study (1) of the underground preparedness of miners at seven underground coal mines showed that only 8% of the miners were satisfied with the firefighting training they were receiving. Some of these miners called for less complacency and more involvement by the workers. Out of 214 miners surveyed, 38% reported that they were notified sometime during their mining career to evacuate the mine because of a fire and 70% were involved in at least one firefighting incident.

The success of safely controlling and extinguishing an incipient mine fire depends on several factors, such as an awareness of the fire hazards, early detection, availability of effective firefighting equipment, quick response time, and trained firefighters. If a coal mine fire cannot be contained by direct firefighting methods within a few hours after discovery, the chances of successfully extinguishing the fire without sealing part of the mine or the entire mine are greatly diminished. Many mine operators and workers are not aware of how fast mine fires can spread, have little knowledge of the magnitude of a detectable fire, nor have much experience in the proper selection and use of modern firefighting equipment. Information on the latest mine fire detection, alarm and extinguishing technologies, and firefighting strategies may be difficult to obtain. Such equipment and techniques could significantly improve the success rate of safe firefighting operations and reduce the risk and occurrence of severe mine fires.

Fire research conducted by the former U.S. Bureau of Mines, as well as actual mine fires, have shown that fires can spread very rapidly. For example, large-scale fire gallery experiments (2) have shown that conveyor belt fires can propagate at rates of more than 0.10 m/s (20 fpm). Yet, many in the mining industry still believe that fire-resistant belting will not burn. Modern fire detection and firefighting equipment, though available, is not often found in underground mines. Longer detection times result when fire sensors with slow response times are employed (3,4,5). Often, mine fires grow out of control due to poor planning, inoperative detection systems, inadequate water supplies, inappropriate firefighting equipment, broken waterlines, failed suppression systems, and improper personal protective equipment.

Mitchell (6) states, "The best facilities and equipment can never compensate for poor preparation." A large part of mine fire preparedness is worker capability, experience, motivation, and training, along with a strong commitment by management. Facilities and programs for mine personnel to learn about the hazards of mine fires, evaluate modern fire detection and firefighting equipment and technologies, and observe the proper methods to combat mine fires are lacking. Mine fire application seminars and briefings, sponsored by MSHA at the National Mine Health and Safety Academy (7) and conducted by NIOSH at PRL's Lake Lynn Laboratory[2] are positive steps. Conti (8) suggested that increasing the mining industry's awareness of the dangers of underground mine fires and conducting periodic fire audits with a well-organized checklist (9) could reduce the probability of having a major fire and improve the current state of fire preparedness.

This paper deals with responders to underground mine fires. Responders in this context are considered the entire workforce, and are categorized as follows: first responders are the first to encounter a fire and initiate firefighting; second responders, or fire brigades, have advanced firefighting skills and personal protective equipment, and take over firefighting activities when the fire becomes too dangerous to fight by first responders; sustained responders, or mine rescue teams, are trained to rescue trapped and injured personnel, fight fires or recover a mine; and evacuating miners responding to an environment that is no longer safe to work in. Technologies to assist evacuating miners during a fire are also discussed.

[2]The NIOSH, PRL conducts open industry briefings on mine fire preparedness to enhance the mining industry's awareness of the dangers of underground mine fires and convey research findings on the latest methods for detection, control, response, and extinguishment of mine fires.

EMERGENCY RESPONSE PREPAREDNESS

Emergency Plan

Confusion and disorder after the initial discovery of an emergency is normal. The first few minutes after discovery are crucial and the key is to minimize the chaos. Since most emergencies are unique, a program detailing every situation is not possible. However, there are certain elements common to all and the preparation of a written emergency plan can reduce the turmoil associated with the emergency. Some of the most important elements of an emergency plan include the following: communication protocol and notification of key officials immediately after discovery of an emergency and updating them at certain intervals afterwards; the responsibilities of certain personnel during the emergency and the selection of a competent person to be in overall control; the development of an advisory and control group; procedures for evacuation and survival; rescue and recovery procedures. The plan must include the surface organization, facilities, and outside sources of assistance for support purposes. Control of outside elements with an interest in the emergency, but not involved with the operation such as news media, relatives and the general public. The entire plan should be reviewed and understood by all the key players. Changes or modifications to the plan must be made immediately and everyone must be kept abreast. Drills to test the effectiveness of responders must be performed at six month intervals.

Responders

First Responders

First responders are the first persons to initiate fire fighting. If a miner who has limited training in extinguishing fires discovers a small fire, the fire may continue to grow before trained personnel arrive on the scene. It is important that miners be properly trained in the use of fire extinguishers, water hoses, and firefighting procedures. They should also know how to immediately and effectively communicate information about the emergency to other miners and key personnel so that they are aware and have a complete understanding of the situation. The best way to convey this communication protocol is through practice fire drills and safety meetings.

When a miner smells or sees smoke underground, they would normally investigate the source. If a fire was found, the miner would attempt to extinguish it using rock dust, fire extinguishers, or water. After discussing this with miners who have firefighting experience and good training, the protocol seems to be: 1) if they are by themselves they would attempt to extinguish the fire and then call the surface to report the incident; 2) if two or more miners are together, one would find a phone to report the fire and the other would attempt to extinguish the fire. Many of the miners who have no hands-on training or firefighting experience are not sure what size fire they would be able to extinguish and, most likely, would find a phone to report the fire and wait for qualified firefighters. Great delays in firefighting efforts would be caused, in the scenario where the miner would wait for help. We all need to remember that time is a critical factor in any fire situation. Two or three seconds saved can mean the difference between a fire's extinguishment or a disaster. The same results can occur by not being prepared for the unexpected event and poor planning.

Second Responders

Fire brigades, or firefighters, are the second responders. Fire brigades, although not common in underground mines, are composed of specially trained and equipped miners that work at the mine site and can rapidly respond to a fire. Usually, a fire brigade consists of eight members, with two teams per mine and several members on each shift. Fire brigades have specialized personal protective equipment, like turnout gear, SCBA's, etc. Their firefighting equipment usually includes effective waterhose nozzles with pistol grips, which allow team members to fight fires for extended periods of time with less fatigue and more accurate control of water patterns and flows. Fire brigades should also be experienced with the use of high-expansion foam generators. By "experienced," I mean that they literally test the foam and foam generator in their mine during training drills and propagate foam in the passageways. This also entails erecting a suitable stopping to be interfaced with the foam generator and/or other stoppings to contain the foam plug. They should ensure compatibility of the foam and mine water supply, proper fittings, and adequate amounts of foam concentrate for a 24-hr period. Brigade members usually handle fire extinguisher and waterhose inspections, and ensure water manifold (fire hydrants, fire taps, etc.) are operational, free of obstructions and adequately identified. The members are ideal for conducting onsite fire training of the general workforce and conducting fire audits.

Sustained Responders

Mine operators most often rely on sustained responders, or mine rescue teams, to save lives during an underground emergency such as a fire, explosion, roof fall, or water inundation. This special breed of miners often place their lives in danger to save others. Team members should be well-trained, physically fit and fully understand the hazards that may await them during rescue and recovery operations.

Historically, underground mine rescue teams have only received training in the course of actual emergencies, or in simulated mine environments, usually on the surface, with placards to identify objects and hazards. Although these surface training exercises enhance their skill levels, it is extremely important that team members are provided with adequate exploration equipment and that training simulations[3,4] are conducted in a realistic manner (10,11,12).

Evacuating Miners

Fire affects a significant proportion of underground miners at some time during their mining career. A study (1) of the underground preparedness of miners at seven coal mines showed that of the 180 miners who were asked if they had ever been notified to evacuate a mine because of fire, 38 percent responded in the affirmative. On the average, 21 percent of the same miners at some time in their mining career said that they had donned an SCSR or FSR in an emergency.

Considering the potential for fire underground, it is important that miners know their escape routes and mine evacuation plans. Fire drills are important exercises, however, from the same study, fire drills in at least some operations mainly consisted of sitting around and talking about what to do if a fire were to occur at the mine, as opposed to a more rigorous hands-on approach.

Training

Over the past several years, NIOSH's Pittsburgh Research Laboratory (PRL) has conducted mine rescue training simulations at its Lake Lynn Laboratory (LLL) and operating mines (13). Figure 1 shows rescue team members fighting a conveyor belt fire in the surface fire gallery at LLL. This training resulted in improved technology and training for mine rescue teams, fire brigades, first responders, and miners in general. For example, existing technologies were identified to help responders during exploration and recovery operations. These included various chemical light shapes, strobe lights, light vests, and laser pointers to identify team members. Most of these devices may be used to mark underground areas and certain mine materials. Strobe lights were used for mapping out escapeways and lasers were used to negotiate travel through smoke. Thermal imaging systems allow rescue personnel to see in darkness and heated areas. These efforts have also resulted in improved disaster recovery training drills and the development of new technology, such as new team lifelines, and inflatable devices for fire suppression and

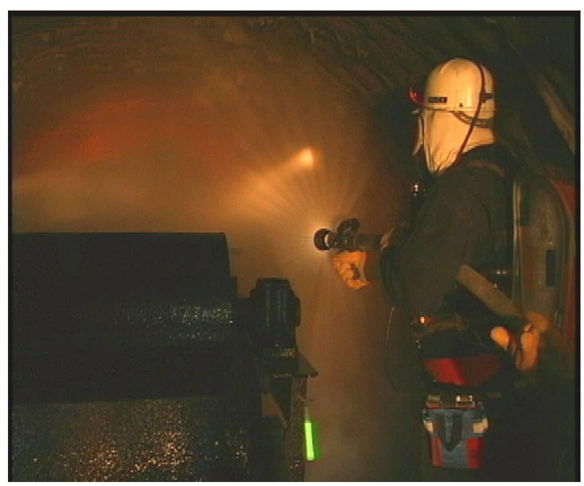

Figure 1. *Rescue team member fighting a conveyor belt fire*.

[3]Mine rescue team training is conducted at the NIOSH, PRL Bruceton Safety Research Coal Mine and Lake Lynn Laboratory Experimental Mine.

[4]The MSHA National Mine Health and Safety Academy provides training for first responders and mine rescue teams.

personnel escape. These technological advancements have improved the state of readiness for rescue personnel and have increased the chances of survival for all personnel escaping from underground emergencies. Other U.S. mine rescue training facilities include Edgar Mine Rescue Training Center, Idaho Springs, Colorado and Central Mine Rescue Unit, Wallace, Idaho.

An important element to consider in any fire safety program is adequate hands-on training for all miners. This is the key link, and a few dollars spent now for training may prevent larger economic losses due to an out-of-control fire. Miners cannot gain effective experience by talking about using a fire extinguisher, watching a video or observing someone else extinguishing a fire. In general, mines have a lot of in-house fire fighting expertise (mine rescue, fire brigades, volunteer firefighters) and these personnel can be utilized to develop an adequate and effective training program. However, if you're a small operator with limited resources, one option for training may reside with the local fire department.

Figure 2. *Extinguishment of a liquid fuel fire with dry chemical.*

The average cost of materials (chemical powder, gas cartridges, fuel) and wages for fire extinguisher training could range from \$65 to \$100 per person. An inexpensive mortar box (shown in figure 2) filled with several inches of water, and a mixture of diesel fuel and gasoline, is suitable for training in the use of fire extinguishers (9.1-kg), fire hoses, hand-held foam generators and other types of fire-fighting equipment. At the same time, miners would have the opportunity to recharge the extinguishers after extinguishing as many fires as they could using one fire extinguisher. Other members can learn by observing and rating the performance of the trainee using a checklist. Hands-on training builds confidence and skill levels and shows miners what to expect in the event of a fire. Figure 3 illustrates a more complicated fire where two miners with larger (68-kg) fire extinguishers are required to fight the fire.

Improved training can be an effective means of bringing about a reduction in the number of fire incidents. Mine fire training (8) can be divided into the following three areas: a) basic training for all miners, b) intermediate training for mine fire brigades/mine rescue teams, and c) advanced training for fire brigade/mine rescue teams. A basic fire training program for all miners should be conducted aboveground and may consist of the following: basic fire chemistry (classes of fires, fire triangle, smoke, heat); assessment of containability of fightable fires; types of

Figure 3. *Extinguishing a 37.2 m^2 liquid fuel fire.*

portable fire extinguishers, hose lines, water nozzles and compatibility of fittings; extinguishing liquid fuel and solid fuel fires with portable fire extinguishers and then with water lines; paper-and-pencil simulations on fighting a small mine fire; mine evacuation procedures and understanding the operations of fire sensors (thermal, smoke, CO) and suppression systems (mobile and fixed).

Intermediate training for mine fire brigades/mine rescue teams would include basic fire training, plus the following: use of handheld and large foam generators; turnout gear and equipment used for firefighting; fighting fires in smoke; wearing SCBA's; paper-and-pencil simulations on fighting fires outby the section; and firefighting strategies (underground fire houses, fire cars or trailers).

Advanced firefighting training would include all of the above skills acquired in basic and intermediate levels, plus the following: combating simulated mine fires in ventilated entries with portable and wheeled fire extinguishers, water lines, and foam generators (the fire would include equipment fires, conveyor belt fires, etc); erecting seals to isolate fire areas; and examining the effect of ventilation on fires and regulating air during a fire. Figure 4 depicts a mine rescue team entering a fire gallery with charged water hoses during an advanced training exercise. Quality training enhances the awareness of mine fire hazards and promotes self-confidence in combating underground and surface mine fires.

All miners need to walk their escapeways and participate in a preplanned fire drills with nontoxic smoke. It gives the workforce an opportunity to learn from the experiences of others and provides a better understanding of how miners will react during an emergency. NIOSH conducts on-site smoke training exercises that allow the workforce to experience first hand, traveling through smoke (visibility ranging from 1 to 3-m) in their mine passageways and at the same time evaluate improved escape technologies.

Figure 4. *Rescue team entering fire gallery.*

Warning Systems

Underground mines rely on alarm systems, such as stench gas, audible or visual alarms, pager phones, telephones, and messengers to warn miners of a fire or other emergency. These systems are often slow, unreliable, and limited in their mine coverage. It is imperative during an underground emergency that all persons, no matter their location, are able to be notified of the emergency. An Australian mining research initiative resulted in the commercial availability of a "paging" system for underground mines (14,15). The Personal Emergency Device (PED) communication system is a "through-the-earth" transmission system that enables communication of specific messages with individuals underground, no matter what their location and without dependence on cables or wiring underground. The low-frequency electromagnetic field can penetrate kilometers of soil and rock to reach the most remote shaft or tunnel, which makes it ideal for underground signaling and paging. This system consists of a personal computer, low-frequency transmitter, portable receiving units, and surface and/or underground loop antennas that can be strategically placed to create an electromagnetic signal that can completely envelop most mines without the use of repeater systems. Messages can be directed to an individual, to a group, or to all underground/surface personnel. Escape routes could be identified, fire brigades and mine rescue teams could be alerted, and key personnel contacted. When the message is received, the cap lamp flashes and the miner can then read the message from the liquid crystal (LCD) display on top of the lamp battery. The message is displayed for one minute. The first demonstration of the system in the United States was conducted at the NIOSH Lake Lynn Laboratory, in November 1990. Figure 5 shows a typical configuration of the wireless system for a mine, depicting capabilities of the communication and signaling system. The transmitter loop antenna is on the surface, and a receiver/transmitter loop antenna is underground. The system can also turn devices such as strobe lights on or off. Additional information on wireless signaling systems and medium frequency radio communication systems for mine rescue can be found in references 15 and 16.

A successful evacuation of miners during the Willow Creek mine fire that occurred in Helper, Utah, on November 25, 1998, was attributed to the PED system. The paging system was activated when miners saw flames and telephoned the dispatcher to evacuate the mine. The PED system allowed a mine-evacuation plan to be safely carried out before the mine passageways filled with smoke. All forty-five underground miners escaped in approximately 45 minutes. There are currently 17 PED systems installed in U.S. coal mines and one in a metal/nonmetal mine.

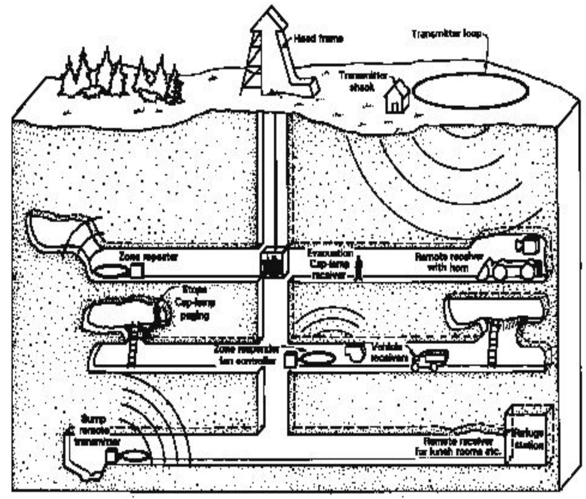

Figure 5. *Conceptual representation of a mine.*

Escapeway Aids

Early detection and rapid response of miners to evacuate the underground passageways before they fill with smoke are key elements to survival. While U.S. Federal Regulations require all underground miners to walk escapeways and conduct fire drills every 90 days in a smoke-free environment, this does not fully prepare them for the conditions that will be encountered in real escape situations. Underground mines mark their escapeways with reflectors or arrows. Usually two colors are used. For example, red might be used to indicate the primary escapeway and green to represent the secondary escapeway. After a period of time, the dust entrained in the airways can collect on the reflectors and decrease their effectiveness, so they may never be seen if the passageways are filled with smoke. A few underground mines use a continuous lifeline for escape purposes. This lifeline or rope would most likely be secured to the rib of the mine starting at the working section and leading to the exiting portal. Some mines are securing the lifeline near the roof in the center of the entry, at an average height of 2-m from the floor, and lower in low seam operations. Depending on the configuration of the mine, the lifeline could be many kilometers in length.

One manufacturer developed a directional lifeline. It consists of standard spools containing 91-m of 0.64-cm polypropylene rope with directional (cone-shaped) orange indicators with green reflective tape installed at every 23-m interval. The tapered end of the cone should always point inby, so that escaping miners would never have to take their hand off the line. Due to the complexity of mine entries that contain crosscuts, mandoors, overcasts, etc., it is suggested that two directional indicators be mounted together on the lifeline approximately 2 to 3-m from a mandoor, etc. This procedure would alert personnel escaping in smoke-filled entries that an obstacle of some sort is nearby.

Another useful escapeway aid is the commercial laser pointer. They are now compact, lightweight, affordable, and have high quality beams. They utilize laser diode technology and several of these handheld battery powered pointers have ranges of up to 732-m. Beam diameters are less than 1-mm. The green laser pointer, with a wavelength of 532 nm and an output power of 1-3 mW, can operate continuously for 2-3 hours. The green wavelength appears brightest to the eye, so a higher power is not required.

During smoke training exercises, the laser pointer was effectively used to negotiate travel through a smoke-filled passageway. Approximately 25 participants during several exercises traveled 300-m in a nontoxic smoke-filled entry, using a lifeline to lead them to fresh air. Visibility ranged from 0.3 to 0.9-m and there were no tripping hazards in the entry. Two to three participants entered the smoky entry at 40 to 60-sec intervals, until all participants were headed toward the fresh air base. Another participant followed this group with only the laser pointer to direct them to the other end (no lifeline) and with their cap lamp turned off. The beam of the laser pointer was continuously moved up and down and left to right. When the beam hit the rib, roof, floor, or other participants, a spot was seen. The participants with the laser reached the fresh air base at the same time as the first participant who entered the smoke. The concept of laser pointers was successful in experiments at the LLL and at an operating mine. Additional research is required to evaluate the feasibility of using higher power lasers to identify escape routes in smoke-filled entries or surface structures. A few companies are exploring the feasibility of storing laser pointers with their SCSR cache.

Another area examined was utilizing high-intensity strobe lights (xenon-white flash tube) strategically located in the entries to map out an escape route for evacuating miners during an emergency. These weather resistant strobe lights, with interchangeable reflective lenses, are compact and lightweight and provide visibility of 180°. The triangular shaped (9-cm each side by 4-cm high), lithium AA battery powered strobe lights could be remotely activated by a wireless through-the-earth signaling system such as the one installed at LLL. Ideally, underground sensors monitor the gases and smoke in the passageways during a fire. By interfacing these data with a computer, the best escape route could be determined and the appropriate strobe lights remotely turned on.

During the in-mine rescue team simulations conducted at LLL, strobe lights were positioned in the center of the entry about 1.8-m from the floor and in the entry crosscuts predetermined to be the best escape routes. The strobe lights were activated by the wireless, through the earth signaling system. Rescue team members were told that a roof fall had occurred and severed the main communication/lifeline. Team members detached themselves from the main communication/lifeline and successfully followed the strobe lights out of the smoke-filled entries to the fresh air base. Team members felt that the strobe lights are easier to follow with their caplamp off. Two hundred and seventy-one miners evaluated five strobe light colors (red, green, blue, amber, and clear) during the simulations. The most visible color in the nontoxic white smoke was green and the least visible color was amber.

A similar simulation was conducted for underground mine personnel in a Western mine. Miners, in groups of five, entered smoke-filled (nontoxic white smoke) passageways and followed strobe lights to the fresh air base. Not only did this exercise allow miners to travel through smoke in their own mine (many for the very first time), but also it gave them an opportunity to evaluate the strobe lights as an escape aid. Miners felt that placement of strobe lights at decision points was quite helpful and interfacing these devices with an audio output would enhance the use of strobe lights for mapping escapeways. The miners felt that the colored reflectors currently mounted in the center of their entries would not have helped them. The concept of strobe lights to identify escapeways and marking mine obstacles was successful in all experiments. In a larger mine, the uncertainties inherent in a complex ventilation system would complicate this process considerably. Additional research is required to evaluate the feasibility of using these devices in larger mines and incorporating audio output with each strobe light unit.

Evacuation Kits

When smoke is encountered underground, visibility is reduced, anxiety levels increase and decision making skills can become clouded. It is extremely important that the crew stays together and have the necessary tools to aid them in a successful evacuation. Some mines have evacuation or escape kits on each section. The kit would contain the following items: rope, lightsticks, chalk, portable lasers, SCSR's, first aid kit, brattice curtain, a mine map, handheld gas sensor and, depending on the mine communication system, an extra radio or pager phone. The rope is used for the crew to attach themselves to and keep everyone together, especially when traveling through smoky passageways. Various colored and intensity chemical lightsticks would be available to mark passageways, so if the crew did become disoriented and lost they would know that they had passed this way before. They can also be used as a light source to negotiate travel through smoke or the high intensity lightstick can be used when administering first aid. Chalk maybe used to mark the ribs, stoppings, etc. (names, direction, date and time). Some mines are considering portable lasers to travel through smoke. Crew members would carry extra SCSR's. A handheld gas sensor can alert the crew of hazardous gases. A pager phone or radio may be used to effectively communicate to the surface or rescue team where the crew is located or underground conditions. Some kits also contain materials to barricade and should only be used as a last resort when all escape routes are blocked. An updated map is essential to travel out of the section and mine to safety.

SUMMARY

Preparedness is an essential element of any underground mine's strategic plan in dealing with an unexpected event, like a fire. Time is a critical factor, and any delay may mean serious injury and the loss of the mine. Therefore, it is important that the fire be detected in the incipient stage and that well trained and equipped miners respond during that crucial period. An important element to consider in any fire safety program is adequate hands-on training for the entire workforce (first, second and sustained responders). Quality training enhances the awareness of mine fire hazards and promotes self-confidence in combating underground and surface mine fires.

Fire affects a significant proportion of underground miners at some time during their mining career. Therefore, all miners need to walk their escapeway and participate in preplanned fire drills with nontoxic smoke. It gives the workforce an opportunity to learn from the experiences of others and provides a better understanding of how miners will react during an emergency.

It is imperative during an underground emergency that all personnel, no matter their location, are able to be notified of the event. Through-the-earth transmission systems like the PED have successfully demonstrated that early warning and evacuation can save lives. If mine passageways are filled with smoke, lifelines and other devices (lasers, strobes, etc.) can aid miners when negotiating travel out of the section or mine. Evacuation kits can keep miners together when escaping.

During an underground fire, responders in general, need to understand the complex environment (fuel supply, smoke, combustible gases, etc.), escape methods and procedures, limits and capabilities, and comprehend when a fire is no longer directly fightable. A few dollars spent now for training may prevent injuries and larger economic losses due to an out-of-control fire.

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