MINE RESCUE TRAINING SIMULATIONS AND TECHNOLOGY

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Abstract

Mine operators often rely on mine rescue teams to save lives during an underground emergency such as an underground fire, explosion or roof fall. It is extremely important that team members are provided with adequate exploration equipment and that training simulations are conducted in a realistic manner. A series of mine rescue training exercises was developed, conducted and evaluated by the National Institute for Occupational Safety and Health (NIOSH) in cooperation with the Pennsylvania Department of Environmental Protection, Bureau of Deep Mine Safety. The exercises were conducted at NIOSH's Lake Lynn Laboratory during 1995 to 1998 and resulted in improved technology and training for mine rescue teams. For example, existing technologies were identified to help rescue teams during exploration. These included chemical lightsticks to identify team members and mark crosscuts and mine materials, strobe lights for mapping out escapeways, and a helmet mounted thermal imaging system to see through smoke. A hands-free communication system showed potential for enhanced communications between team members and the fresh air base. A new high-visibility team lifeline that allows for flexibility of movement between team members was developed. A positive-pressure inflatable escape device (IED) was used to isolate the "hazardous" environment from fresh air and allow rescue team members to traverse through. An inflatable feed-tube partition that can rapidly block large openings such as underground passageways and simultaneously provide a feed-tube for high-expansion foam generators was also deployed for several simulations.

During the simulations, mine rescue team members donned self-contained breathing apparatuses (SCBA) and traversed more than 305-m of mine passageways filled with nontoxic smoke. Visibility ranged from 0.3 to 0.9-m. In one area of the mine, a kerosene heater was used to simulate a fire and reduce the oxygen concentration. In another area, a 1.5 pct methane zone was established. The team members searched for "victims," mapped the

passageways, built temporary stoppings and ventilated the smoke-filled entries. The teams indicated that the simulations were challenging and very informative.

Background

A recent survey conducted by the Mine Safety and Health Administration (MSHA) indicated that there are 281 state and company mine rescue teams in the United States; 157 metal & nonmetal mine teams and 124 coal mine teams. This dedicated group of miners often put their lives in jeopardy to save others. It is important that team members are provided with the latest personal protective equipment, be well trained, physically fit, and fully understand the hazards that may await them during rescue, exploration and recovery operations. Very often, rescue teams receive hands-on training during actual emergencies, or in simulated mine environments with placards to identify objects and hazards. This paper deals with improved training simulations and new technology for mine rescue teams.

Mine rescue training began in the United States in 1910, the year the U.S. Bureau of Mines was created. Joseph A. Holmes, the Bureau's first director, sought a training vehicle (railroad cars) that would give the mining industry a cadre of mine rescue specialists who would be prepared to respond to mine disasters. The training efforts evolved into local and regional competitions and, a year later on October 30, 1911, the first national mine-safety demonstration was held at Forbes Field, in Pittsburgh. The demonstration was planned and managed by engineers of the Bureau, with the aid of miners and coal operators of the Pittsburgh district. It embraced exhibits that showed the character of nearly every branch of the Bureau's investigative work in relation to mine accidents. The demonstration included first aid and mine rescue work, and special coal-dust explosions at the Bureau's experimental mine at Bruceton, PA. Approximately 15,000 persons attended the demonstration. The field exhibits were witnessed by President William H. Taft who presented Red Cross medals and first aid packages to rescue team captains, and many National and State government officials. Teams of miners trained in first aid and rescue work from every coal-mining State took part in this stimulating demonstration.

Mine rescue contests are still conducted on a regular basis to sharpen skills and test the knowledge of miners who may one day be called upon to respond to a real mine emergency. The contests require teams of six members each to solve a hypothetical rescue problem while being timed and observed by judges according to precise rules. The simulated problem involves trapped miners who have to be found and rescued. State and Federal mine safety experts evaluate each team as they work through their rescue problem in a simulated mine environment. Teams are rated on adherence to safety procedures and how quickly they complete their task.

Federal regulations, as spelled out in 30 CFR Part 49, Mine Rescue Teams, require that every operator of an underground mine will assure the availability of mine rescue capability for the purposes of emergency rescue and recovery. Part 49.8 discusses training for mine rescue teams. In particular, underground sessions will be conducted every six months and include the wearing and use of breathing apparatus; use, care, capabilities, and limitations of auxiliary equipment; advanced mine rescue training and procedures; mine map training and ventilation procedures, etc.

Over the past several years, NIOSH's Pittsburgh Research Laboratory has conducted mine rescue simulations at its Lake Lynn Laboratory near Fairchance, PA. Working agreements were established between NIOSH and the Pennsylvania Bureau of Deep Mine Safety and several mining companies to increase the operational effectiveness of their coal mine rescue teams and evaluate new and emerging technology. These efforts have resulted in improved disaster recovery training drills and the development of new technology such as a high-visibility team lifeline, an inflatable partition for high-expansion foam generators, and a positive-pressure inflatable escape device. Existing technologies, such as the use of chemical lightsticks for identifying team members and thermal imaging equipment, were evaluated. Current rescue protocols and strategies were also assessed.

Lake Lynn Laboratory (LLL)

The NIOSH Pittsburgh Research Laboratory's LLL, formerly a limestone mine, is now a multipurpose research facility used to conduct mining health and safety research (1). Lake Lynn Laboratory's underground layout, including the locations of antenna loops for a wireless electromagnetic signaling and warning system, is shown in figure 1. The new entry dimensions of the underground mine range from 1.8 to 2.4-m high and from 5.3 to 6.3-m wide. The average dimensions are 2.1 and 5.8-m, for an average cross-sectional area of 12-m^2. The underground configuration of the new entries covers approximately 95-km^2, with an overburden ranging from 50 to 100-m. The unique nature of the facility allows it to be readily adapted for elaborate mine rescue team simulations in smoke-filled entries.

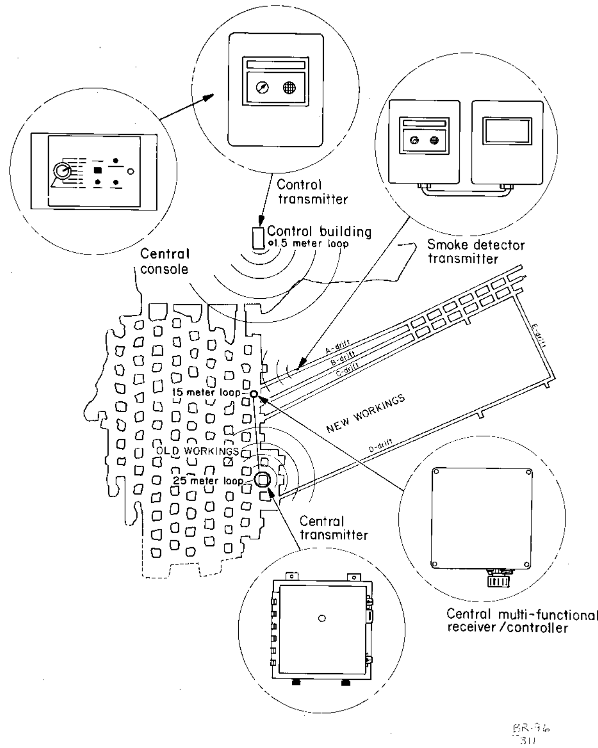

Figure 1 - Plan view of Lake Lynn Laboratory's undergroundmine, including a diagram of the wireless electromagnetic signaling and warning system.

The LLL wireless signaling system transmits an emergency warning that can quickly reach every underground miner. 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 low-frequency transmitter that can be strategically placed to create an electromagnetic signal that can completely envelop most mines without the use of repeater systems. The transmitter loop antenna is on the surface, and a receiver/transmitter loop antenna is underground. The person-wearable receivers are small, lightweight modules incorporated into the miner's cap lamp assembly. Upon receiving an emergency or paging signal, the cap lamp begins to flash, which in turn alerts the miner to evacuate the mine or call the surface for a message, depending on which signal is received. The system can also turn devices such as strobe lights on or off. Additional information on wireless signaling systems can be found in reference 2.

Identifying Team Members

NIOSH attempted to address issues raised by rescue team members that participated in the simulations. One of the main concerns of the rescue teams was identifying other team members and marking locations, such as crosscuts, brattice curtain, cribbing, and other items that may be found in the smoke-filled entries, or just maintaining a reference point. Chemical lightsticks, a technology that has been around for years, were found to be a valuable tool for underground rescue teams. The chemical light is nonflammable and not a source of ignition, and it is weatherproof, maintenance free, and nontoxic. To activate, just remove the stick from the package, bend, snap and shake. Instantly a source of light exists that can vary in intensity and duration. The brightest lightstick would last 30-min; the least brightest, 12-hours.

The lightsticks were assessed by the team members during the simulations, both in white nontoxic smoke and black toxic smoke produced from conveyor-belt fires. Four lightstick colors were evaluated; clear, green, red, and yellow. Team members, as shown in figure 2, attached these lightsticks to the back of their helmets with plastic ties. They can be also placed on the floor at various critical locations and on obstacles during exploration. Figure 3 shows the responses of the rescue team members for the most visible color lightstick in these smoke-filled environments. Of 114 mine rescue team members participating in the white nontoxic smoke simulations, 74.4 pct identified green as the most dominant color; clear was the least visible color. Out of the 49 rescue team members that participated in fighting the conveyor-belt fire, 77.5 pct felt that green was the most dominant color; yellow was the least visible color. Lightsticks are now a crucial component for these team members. Other chemical light shapes and intensities are currently being considered.

Figure 4 -Photograph of high-visibility team lifeline.

Figure2 - Chemical lightsticks attached to the back of rescue team members helmets.

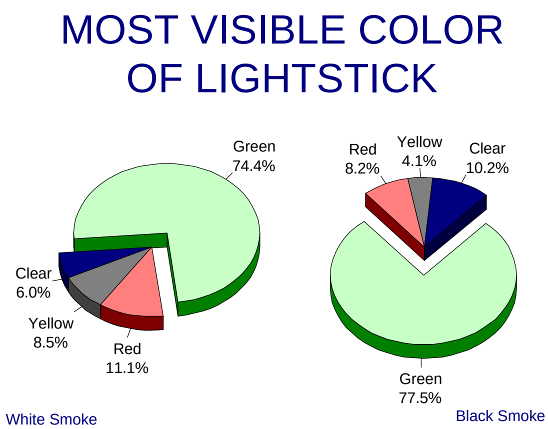

Figure3 - Response of the rescue team members for the most visible color lightstick in these smoke-filled environments.

High-Visibility Team Lifeline

Very often rescue team members are attached to a team lifeline connected to the main communication/lifeline that extends from the fresh air base. Team members are fixed along an 8.5-m length of rope at various distances between the captain and tail-person. Team members have reported that if one person would trip and fall, other team members could be pulled down with the falling team member. If the rope were entangled around debris, finding it was difficult.

These concerns were solved by using a high-visibility rope, shown in figure 4, with filaments made of reflective material braided directly into the sheath. The reflective filaments, based on glass-bead technology, generate a return more than 1,000 times brighter than plain, white rope. Double-locking snaps were attached to both ends of the rope, with three or more snaps in-between both ends. D-shaped carabineers were then attached to the snaps. Team members, shown in figure 5, attach the carabineers to their mine belt and have freedom of movement to slide between the captain and tail-person, providing flexibility of motion to do activities such as carrying supplies, erecting temporary ventilation controls and supporting roof. This also alleviates tripping and falling problems.

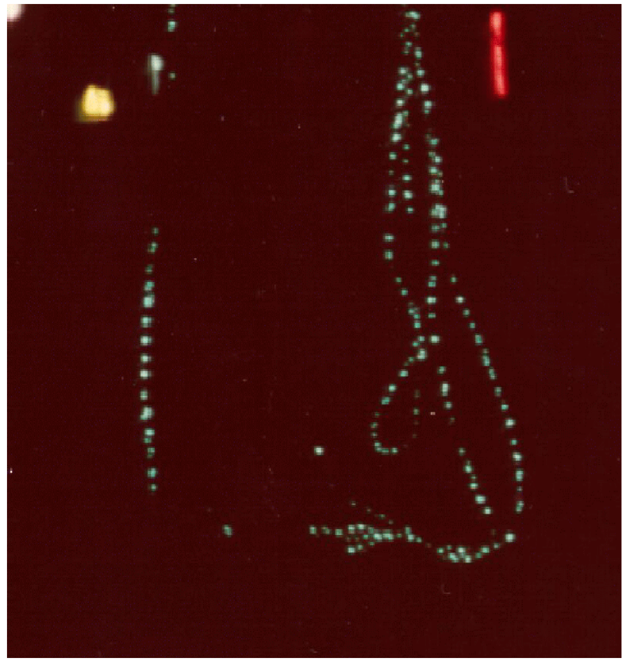

Figure5 - Rescue team members attached to the high-visibility team lifeline.

Communications

Communication is a major issue and concern of rescue teams. Team members are often unable to hear other members, and at times the communication signal to the fresh air base is also faulty. This can be very frustrating to team members, especially in high stress situations. The current practice is the tail-person, who has the earphones and microphone, talks to the fresh air base. At LLL, a radiating transmission line, base station and repeater system along with two-way radios are used for daily communications between employees. The in-mine transmission line leaks a controlled amount of RF energy over its full length so that two-way radio communication can be maintained for a considerable distance through the mine passageways and to the surface. The cable line is not frequency sensitive and can be used for high band VHF and UHF simultaneously.

The concept of speaking and hearing through the ear is not new, but its application in the voiceducer (3) two-way communication device achieves a high level of performance. The voiceducer combined with a two-way radio provides two-way communications from a small device worn in the ear. Although it looks like an ordinary earphone, the earpiece contains both an accelerometer microphone and miniature receiver component. The ear microphone detects speech-induced bone vibrations via direct contact with the ear canal wall. The miniature earpiece leaves the hands free and face unobscured when worn by rescue personnel with breathing apparatus. When in high ambient noise, suitable earmuffs can be worn. The user consequently is afforded a much greater degree of freedom than has previously been possible with two-way radios. Experiments with rescue teams at LLL indicated this system showed potential. Both the captain and tail-person could communicate with the fresh air base.

Additional research efforts could include inserting a wire antenna into the main line that extends from the fresh air base or wrapping the main communication line with a wire antenna. The latter example could serve as a backup communications system. During exploration, team members would have the antenna with them and can use the voiceducer. By having several channels on the radios, communications between team members or the fresh air base can be controlled.

Another new concept that will be evaluated with rescue teams is the head-contact microphone (4). It is a hands-free radio microphone that can either be strapped onto the forehead or incorporated into a helmet headband. A rescue member need not speak into this microphone; it gathers sounds from vibrations transmitted through the skull and works whether the rescue member is wearing an SCBA or not. Little background noise is pickup by the microphone, so rescue members need not shout. Ear speakers are suspended on the helmet and a touch sensitive on/off switch can easily activate the system by a gloved hand.

Strobe Lights

Another area examined was utilizing high-intensity (a xenon-white flash tube) strobe lights 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 (100 gm) and provide 180° of visibility. 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 would 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. 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 by keeping their cap lamps off, the strobe lights were easier to follow. Five strobe light colors (red, green, blue, amber and clear) were evaluated by 81 miners. Figure 6 shows that the most visible color in the nontoxic white smoke was green and the least visible color was amber.

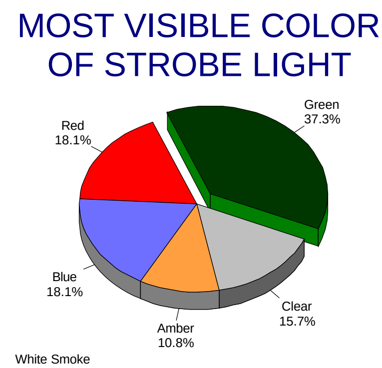

Figure6 - Responses of the rescue team members for the most visible color strobe light.

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 these strobe lights to the fresh air base. Not only did this exercise allow miners to travel through smoke in their mine (many for the very first time), but it gave them an opportunity to evaluate the strobe lights as an escape aid. 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 was successful in experiments at the Lake Lynn Mine and several isolated passageways of a Western mine. In a larger mine, the uncertainties inherent in a complex ventilation system would complicate this process considerably. Additional research would be required to evaluate the feasibility of using these devices in larger mines and incorporating audio output with each strobe light unit.

Vision Enhancement

Firefighting and similar emergency response activities often impair vision due to dense smoke or darkness. Vision enhancement in such circumstances is a profound benefit for completing the assigned task. Infrared (IR) thermal imaging enhances the users vision when visible light is inadequate. Thermal imaging both restores vision and provides significant additional information to the user not otherwise possible to obtain. The technology increases the responder's understanding of the environment, thus enhancing safety and the ability to accomplish the task. The first documented civilian life saved with thermal imaging technology was during a 1988 fire that occurred in New York.

Recent improvements in the sensitivity and resolution of uncooled IR imaging sensors have provided the major enabling technology for the development of practical helmet-mounted IR vision system (5). In 1995, Cairns & Brother Inc. introduced the first commercially available hands-free helmet-mounted IR imaging systems (6). Firefighters use the Cairns IRIS to see through dense smoke and darkness in structural fires. The system processes the signal and displays a black and white image that shows the hottest areas in white, the coldest as black and the temperatures between as varying shades of gray. It can detect 0.3° C differences in temperatures. The sensor is a specially coated 15-mm Germanium lens that filters out everything except 8 to 14-micron infrared radiation. A rechargeable nickel cadmium battery pack provides 30-min of continuous, uninterrupted use at ambient temperature.

The first demonstration of the Cairns IRIS in an underground mine was conducted at Lake Lynn Laboratory on February 8, 1996. The capabilities of the hands-free thermal imaging camera in the smoke-filled mine passageways suggested that it indeed had merit for mine rescue exploration. Figure 7 shows a rescue team member wearing the Cairns IRIS and exiting a smoke-filled entry.

Figure 7 - A rescue team member wearing the Cairns IRIS and exiting a smoke-filled entry.

Figure 8 - Photo of inflatable feed-tube partition in the Lake Lynn Experimental Mine.

Inflatable Feed-Tube Partition

When mine fires can no longer be fought directly due to heat, smoke or hazardous roof conditions, high expansion foam (HEF) may be one way to remotely quench the fire. The firefighting personnel and HEF generator can be located away from the immediate vicinity of the fire at a less hazardous underground location. The HEF is a convenient means of conveying water to a fire (*7,8*). It quenches or extinguishes a fire by diluting the oxygen concentration through the production of steam, blocking the air currents to the fire, and blocking the radiant energy from the fuel (*9*) to other combustibles.

To effectively use the foam method for remotely fighting fires in underground mine entries, it is often necessary to construct, at some distance from the fire site, a partition or stopping in fresh air to separate the foam generator and its operators from the smoke and toxic fire products. If this is not done, the HEF could flow back over the foam generator, rendering the fire attack futile. This problem is especially acute when the fire is found uphill in a sloping entry. Concrete block, wood, plastic sheeting, mine brattice cloth or similar materials have been used for such partitions. Often, mine entries have irregular dimensions to which the partition must conform to avoid leakage around the periphery. Construction of such partitions can be a time-consuming process. After the partition is constructed, a hole must be cut through it to allow passage of the high expansion foam from the foam generator to the fire site. During a recent underground simulation for mine rescue teams and fire brigades in an operating coal mine, it required 77 min to construct a partition from wood, metal and brattice curtain, and start the foam propagating up the mine entry.

To address the drawbacks of constructing a partition for HEF generators, the inflatable feed-tube partition (IFTP) (*10,11*) was developed. The IFTP, shown in figure 8, is a lightweight, inflatable rectangular bag. The device can rapidly block large openings (within 15 min), such as those in underground mines, and simultaneously provide a feed-tube for high expansion foam. This allows firefighting foam to freely flow to the fire site and control or extinguish the fire.

The portable IFTP can be easily transported to a mine passageway leading to a fire area and then be inflated by a permissible fan/air blower or a compressed air source (air source must be kept on to compensate for leakage). The fabric used for the IFTP is made from a water and heat resistant, lightweight fabric (0.076-mm thick), such as chemically treated, rip-stop nylon. The IFTP could also be fabricated from a material such as Mylar or fire-resistant materials. The shape and size of the IFTP depend on the passageway dimensions in which it may be used. For example, for a mine entry 2.1-m-high by 5.8-m-wide, the IFTP would take the shape of a slightly oversized rectangular bag approximately 2.6-m-high by 6.1-m-wide and 3.1-m-long. Experiments in the Lake Lynn Experimental Mine showed that a 2,800-L/s diesel-powered (fixed driving force), high-expansion foam generator with the IFTP could push a foam plug 245-m through an entry 2.1-m high by 5.8-wide with a 4.3 pct rise in elevation, before the foam generator failed to push the foam plug further. Additional information on the use of foam and partitions can be found in references 8, 11 and 12.

Positive-Pressure Inflatable Escape Device

Another conceptual use of an inflatable bag (*13*) is a positive-pressure, inflatable walk-through escape device (IED). This rapidly deployed device, with its "pass-through" feature, allows extra time for personnel evacuation by isolating a smoke-filled entry from fresh air and is shown in figure 9. The IED would be strategically placed in a mine entry, and then be either manually or remotely deployed during a mine fire. Mine personnel escaping from the fire area would enter the bag from the smoke-filled side, and exit into fresh air. Since the bag is under positive pressure, it would be impervious to outside contaminates, such as smoke and gaseous combustion products. If the inflating air was clean compressed air, the bag could be used as a temporary shelter (*14*). The use of a fan for inflation, however, would require that the fan remain in fresh air or that filters be installed on the fan to cleanse the mine air of any contaminants.

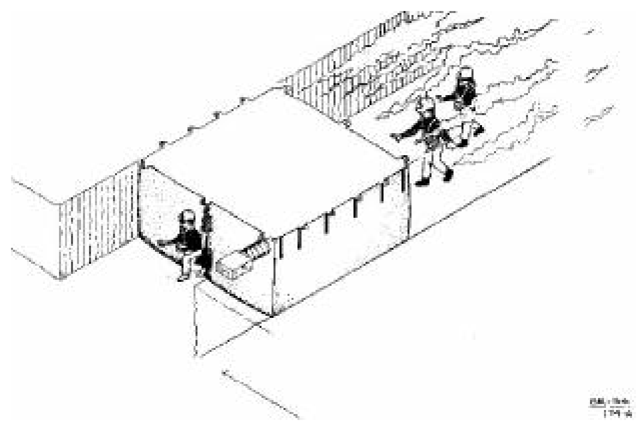

Figure 9 - Conceptual drawing of the positive-pressure, inflatable walk-through escape device.

Another potential use for this device could be realized during mine recovery operations following a fire or explosion. It has also been very effective during the mine rescue simulations conducted at LLL and an operating coal mine. The inflatable escape device was used as an airlock system during exploration by mine rescue teams. The IED could be rapidly advanced as mine recovery continued. This device successfully isolated smoke-filled entries from fresh air, and mine personnel effectively passed through the device to the fresh air base or back into the smoke-filled entries.

Mine Rescue Team Simulations

The "Triple R Coal Mine" simulation was one of the most aggressive mine rescue team exercises conducted in the Lake Lynn Experimental Mine. A longwall panel fire resulted from an explosion and team members were instructed to locate three missing miners. Rescue team members donned Draeger BG-174 self-contained breathing apparatuses and traversed more than 305-m of mine passageways filled with nontoxic smoke. Visibility ranged from 0.3 to 0.5-m. The team members moved the fresh air base, searched for "victims," administered first aid, and mapped the passageways. The instructors' simulation map, shown in figure 10, includes the locations of the two fatalities, an injured miner, and other pertinent information. The positive-pressure inflatable escape device was used by rescue team members to enter the "smoke-filled" passageways from a fresh air base. Various colored chemical lightsticks identified team members and were used to mark strategic locations in the mine. In one area of the mine, a kerosene heater simulated a fire. A fiberglass duct, 81.3-cm in diameter by 6.1-m in length, was placed on the floor in one crosscut. Surrounded by an inflatable bag, the duct simulated a low roof and was the only means to enter the other entries. Two teams per day participated in the exercise. One team evaluated the Cairns IRIS helmet-mounted thermal imaging camera during exploration and the other team used conventional methods. The captain, tail-person and fresh air base from both teams used a hands-free, wireless communication system. The simulation indicated that new protocols need to be developed when mine rescue teams explore with the Cairns IRIS because the team member with the thermal imaging camera can travel smoke-filled entries much more rapidly than other team members.

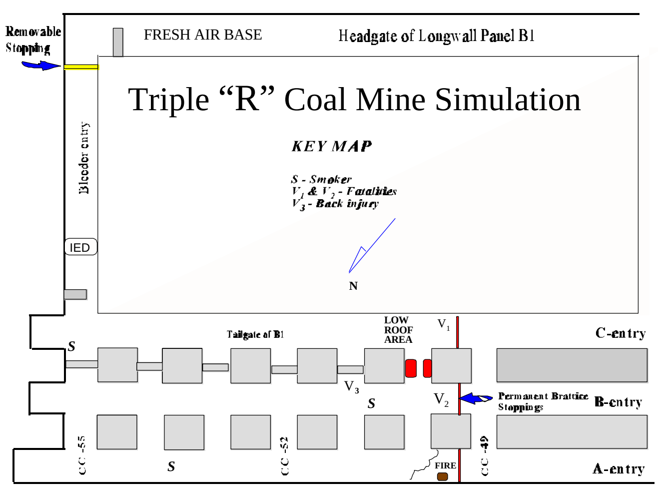

Figure 10 - Instructor's Triple "R" Coal Mine simulation map.

The "Red Creek Mine" simulation focused on fire and ventilation. The team members searched for "victims," mapped the passageways and constructed temporary stoppings. In one area of the mine, a kerosene heater was used to simulate a fire and reduce the oxygen concentration to 18 pct. In another area, a 1.5 pct methane zone was established. Handheld sensors carried by the rescue team members alarmed when they entered these areas, alerting them to the "hazardous" condition. A flowchart of how two teams completed the tasks is shown in figure 11. The data suggest significant differences in how teams go about exploring and solving the problems. For example, Team-1 completed all eight tasks within 84 min. However, 85 min were required for Team-2 to complete only four tasks. The tasks included locating and extinguishing the fire, identifying the methane zone, finding the two missing miners and a mining scoop, setting up the brattice curtain and ventilating the smoke-filled entries. The simulation suggested a wide variation in the way some teams go about mapping the entries during exploration. This includes differences within each team between the maps kept by the team map person and the fresh air base, and differences between the individual teams in deciding what information is important to map. Some teams document on the map everything they see and others are very sketchy; for example, the type of symbol used, or noting the location and visibility of smoke in the entry, or keeping track of the time and the lowest SCBA pressure when doing a team check. Team members indicated that the exercise was a challenging and a very realistic simulation.

During another simulation, rescue team members were briefed on the protocol to be used during the extinguishment of a conveyor-belt fire. Three-person teams (under apparatus) on a short team lifeline were led into the Lake Lynn Fire Gallery, upstream of the growing fire. After 12 min, two teams of three members each carrying charged waterlines were escorted into the fire gallery through both doors. These teams controlled the rollback smoke and extinguished 4- to 5-meters of burning conveyor belt.

At the end of each simulation, the team members answered a series of questions that included demographics (age, mining and mine rescue experience, special training or routine tasks), usefulness of the fresh air base briefing, how the team members made decisions, anxiety levels and physical demands of the rescue operation. The rescue team as a whole was then debriefed. This open forum offers an opportunity for team members to engage in some lively conversation about the simulation. For example, how was the strategy developed for exploring the entries, and how good was the communication between team members and the fresh air base. Team members, company personnel and State officials all agreed that the simulations are extremely beneficial. The program offers a unique opportunity to develop and conduct realistic simulations for mine rescue teams at Lake Lynn Laboratory and evaluate technology for mine rescue operations.

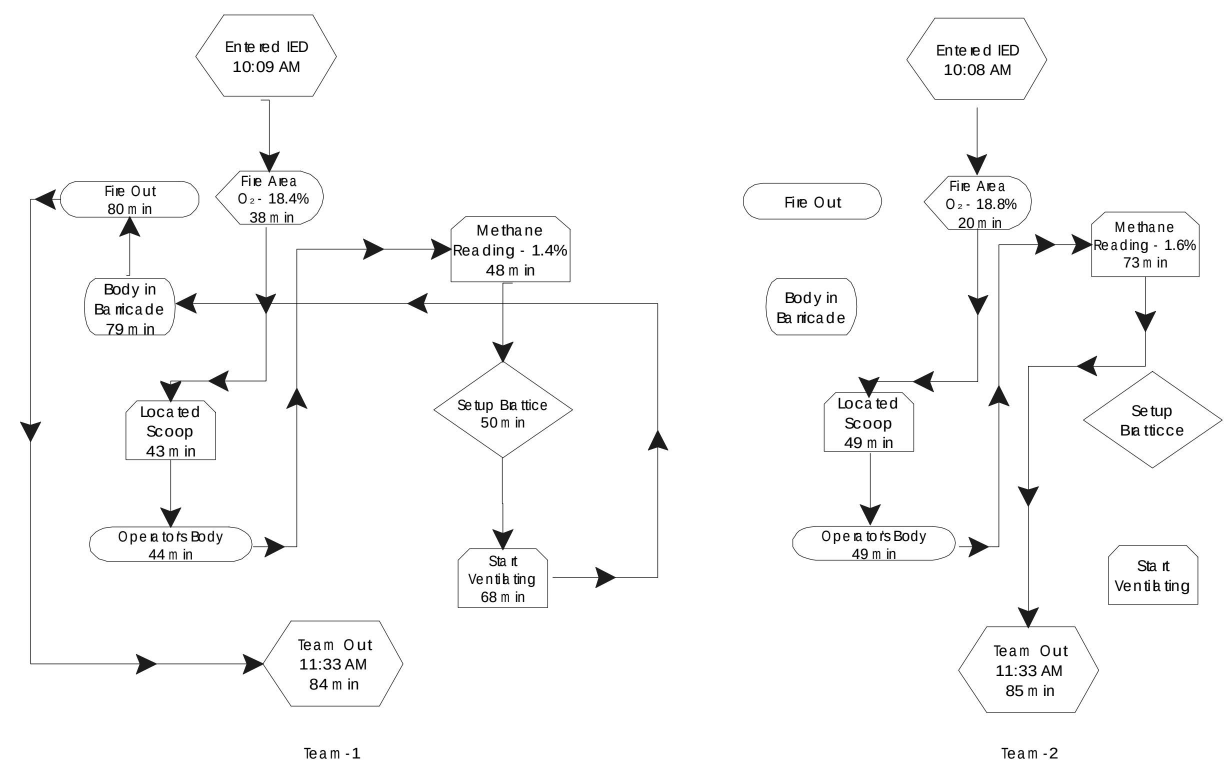

Figure 11 - *Flowchart depicting two teams completing the training simulation tasks.*

Summary

This cooperative effort offered an excellent opportunity to evaluate new and existing technology that may be used for underground mine rescue operations. For example, rescue teams have identified green as the most visible colored lightstick in both white and black smoke. These teams have now added lightsticks to their cache of rescue team supplies.

By using the high-visibility team lifeline, team members have freedom of movement between the captain and tail-person. They can visually see the rope and are more flexible to do activities such as carrying supplies, erecting stoppings and supporting roof. This also alleviates tripping and falling problems.

Utilizing the voiceducer, with the present radiating transmission line at Lake Lynn Laboratory, has shown potential for improved wireless communications for mine rescue teams. Additional research is required to incorporate the antenna into the main lifeline.

Strobe lights were useful for mapping out an escape route for evacuating miners. Activation of the strobe lights by the wireless, through the earth signaling system, was successful. Additional research would be required to evaluate the feasibility of using these devices in larger mines and to incorporate audio output with each strobe light unit.

The hands-free helmet mounted thermal imaging camera has merit for mine rescue exploration in the smoke-filled mine passageways. However, the simulations suggested that new protocols need to be developed when mine rescue teams explore with the Cairns IRIS, because the team member with the thermal imaging camera can travel smoke-filled entries much more rapidly than other team members.

Both inflatable devices have shown merit in providing a relatively rapid method for isolation of a mine fire and for use with a foam generator for fire suppression, or for personnel escape and rescue. The inflatable partition can rapidly block large openings, such as those in underground mines, and simultaneously provide a feed-tube for high expansion foam. The inflatable escape device could be used as an airlock system during exploration by mine rescue teams and could be rapidly advanced as mine recovery operations continued.

Since the onset of rescue team simulations at Lake Lynn Laboratory, several team members have decided that rescue work was not for them. Some rescue teams, who trained in smoke for the first time, were so confused that they gave up and had to be rescued. Overall, the strengths of the team and its members have improved since their initial exercise. For example, confidence levels have increased, and members are now working as a team, thinking through the problem together. Teams are successfully accomplishing their goals by replacing contest rules and placards with realistic hands-on-training exercises.

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