ADVANCES IN MINE EMERGENCY COMMUNICATIONS

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ABSTRACT

Since 1981, Federal mining law has required every miner working in underground coal mines to have a self-contained, self-rescuer (SCSR) available for use in emergencies. Some miners that have escaped from fires using SCSR's have reported that they had to remove their mouthpiece to talk during escape, thus compromising the protection afforded by the SCSR. If miners are in thick smoke during an escape, they may have trouble if they become separated from their group. The visibility can be so poor that separation can occur at very short distances. To address this problem, two-way, FM radios were built into the SCSR to improve the ability to communicate should the miners be separated over relatively short distances.

The SCSR prototypes built and used in testing included both two-way radios and improved mouthpieces. Comparison studies were conducted using combinations of the new and old mouthpieces, and trials using the radio or not using the radio. Subjective judgements indicate that communication ability was significantly improved using the prototype devices.

Communication problems have been encountered with teams using standard voice-powered communications systems. Mine rescue teams perform rescue and recovery work under extremely hazardous conditions, life lines are a standard part of mine rescue team equipment. Leaky feeder and quasi-leaky feeder life line communications systems provide significant improvements over standard systems. These improved systems allow all members of the team to communicate with each other and their base of operations. These innovations will significantly enhance the safety of mine rescue operations.

INTRODUCTION

Since 1981, Federal mining law has required every miner working in underground coal mines to have a self-contained, self-rescuer (SCSR) available for use in emergencies. These devices provide a minimum of one hour of oxygen to escaping miners in the event of an emergency evacuation due to mine fires or explosions. Miners that have escaped from several recent mine fires using SCSR's have been interviewed, and some have reported that they had to remove their mouthpiece to talk during escape, thus compromising the protection afforded by the SCSR.

In September 1989, an explosion occurred at the Pyro Mining Company's No. 9 Slope, William Station Mine in Union County, Kentucky, resulting in the deaths of ten underground coal miners. Five of the nine persons who used filter-type self-rescuers (FSR's) while trying to escape the explosion area did not survive. According to the survivors, several of the victims removed their self-rescuers in an attempt to talk with each other. As a result of this incident, an MSHA report (1990) recommended that MSHA, in conjunction with the U. S. Bureau of Mines, should examine the feasibility for developing self-contained self-rescue devices which allow communication without removal of the mouthpiece.

Successful communication is critical during an emergency evacuation. Miners need to be able to communicate during escape in order to make decisions and to provide emotional support to one another in a life threatening situation. This requires a full range of two way speech. Simplified communications, such as cap lamp or hand signals, simply do not begin to provide the necessary psychological support, and decision making ability needed during a crisis.

SCSR Communication Problems and Solutions

The main problem in trying to communicate while wearing an SCSR is the mouthpiece. It interferes with normal speech in ways that are difficult to compensate for. The teeth and lips can not be brought together as they are in normal speech. This interferes particularly with words that contain "m" or "b" sounds. An improved mouthpiece was developed which helps to overcome the interference. Figure 1 is a photograph of the improved mouthpiece that was developed during a one year research effort. A speech pathologist and an oral surgeon were included in the team that designed the new mouthpiece. This part is more pliable, and considered by some using it, to be more comfortable. If miners are in thick smoke during an escape, they may have trouble if they become separated from their group. To address this problem, two-way, FM radios were built into the SCSR to improve the miner's ability to

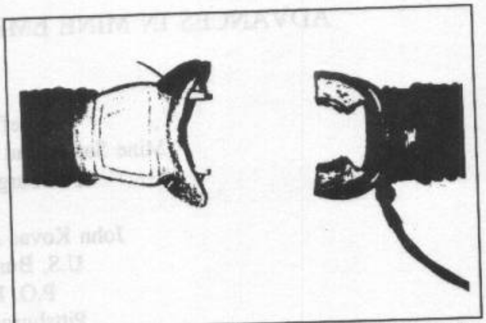

Figure 1.--New mouthpiece (left) vs standard mouthpiece

communicate at a distance. The effective range of this system is currently about 30 meters. Communication at this range without the radio is virtually impossible, with or without the improved mouthpiece. Figure 2 is a schematic diagram of an SCSR equipped with radio communications.

Subjective judgements indicate that communication ability is significantly improved using the prototype devices. It is still difficult to talk with the SCSR on; however, the situation is improved from the unmodified rescuer. Further studies will focus upon repackaging and improving the radios, and performing objective tests of speech clarity.

Life Line Communications Problems and Solutions

Mine rescue teams perform rescue and recovery work under extremely hazardous conditions. Federal law requires each operating mine to have ready access to at least two certified mine rescue teams. Only highly trained and motivated persons are permitted to work on these teams due to the demanding nature of their operations. Becoming separated from the team in limited visibility could be a fatal mistake when there is no other way to re-establish communications. Therefore, life lines are a

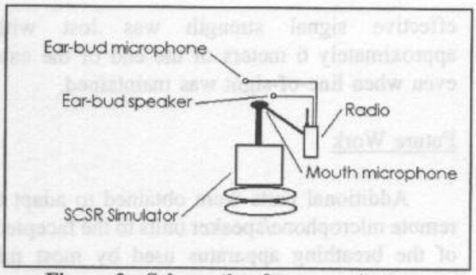

Figure 2.--Schematic of communications equipped SCSR

standard part of rescue and recovery operations. The type of life line used by the majority of mine rescue teams is a 300 meter section of a relatively thick cable that supports a sound-powered communications system. This cable is fed off a cable reel as the team advances. It is cumbersome to handle, often gets caught on obstacles, such as mining equipment, and it is difficult to pull over such equipment or around coal pillars (blocks of coal left during the mining operations to help support the mine roof). This type of communications system only allows one member of the team (the communications officer) to talk back to his base of operations (the fresh air base).

Standard leaky feeder cable systems have previously been investigated for use in mine rescue communications. Such systems were found to be too rigid and heavy. Mine rescue communications, however, could , in fact, benefit from the properties of a leaky feeder system. Such a system would allow all team members to talk to each other and the fresh air base.

Since the mine rescue team members are dependent upon their self-contained, breathing apparatus (SCBA) for survival, they cannot launch individual expeditions far afield from the rest of the team members. The only margin of safety that can be provided comes from remaining close to the others in the group along an established search path. Thus the range limitations of leaky feeder cable fall within boundaries that are already established by safety considerations.

Description of Equipment Used

A communication test was set up in the Bureau's Safety Research Coal Mine at Bruceton, PA, using Motorola MX330 hand-held radios, Radio Shack RG8 coaxial cable, and a yagi antenna. One of the radios was connected to the RG8 cable by an external antenna jack. The other two hand-held radios were operated without any physical connection to the cable. The RG8 cable acted as a quasi-leaky feeder.

The MX330 is an MSHA approved radio that can be used in explosive atmospheres. For the test, the radios were equipped with a remote microphone and a replaceable, approved, 3-hour, ni-cad battery. The radios operated on 464.5-469.5 MHz. The RG8 cable was divided into three, 75 meter sections, two 15 meter sections, and one 45 meter section to evaluate the convenience of carrying. Each end was equipped with an "N" type connector. The "N" type connector was selected because it makes a secure connection. It is screwed together and is water resistant. At each joint a "T" connector could be placed to allow for branching. The yagi antenna was placed on the end of one of the branched sections. The radios can be damaged by insufficient impedance in the antenna circuit. The yagi antenna provides this impedance load in addition to its broadcast function. Figure 3 is a schematic diagram of the equipment used during the in-mine tests of this system.

Results

The radios were taken into the mine to test the range without the assistance of the RG8 cable and antenna. The communications were clear and understandable as long as line-of-sight was

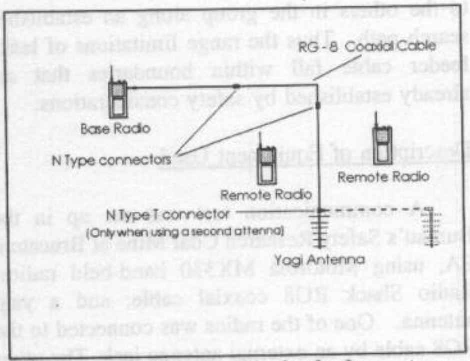

Figure 3.--Schematic of leaky feeder system

maintained between radios. Once line-of-sight was lost, the reception can be broken in as little as 6 meters from the line of sight.

In the next test situation, a single 75 meter length of cable was connected to the radio and the yagi antenna was connected to the end of the cable. This combination seemed to increased the effective distance in two ways. Not only was the distance between the two radios increased by the length of the cable, but the yagi antenna was a more efficient broadcast source/receiver than the built-in antenna. It was also found that the cable needed to by hung from the rib and not left lying on the mine floor in order to achieve acceptable results.

In the succeeding trials, the antenna was placed progressively closer to the base end of the cable as additional cable was added. The effect of adding cable was to reduce the signal strength at the remote antenna.

The final layout consisted of 225 meters of cable with the yagi antenna placed 75 meters from the base unit. In this configuration, communication away from the antenna, could be maintained as long as the cable was in the same entry as the remote radio. In this arrangement, effective signal strength was lost within approximately 6 meters of the end of the cable, even when line-of-sight was maintained.

Future Work

Additional parts were obtained to adapt the remote microphone/speaker units to the facepieces of the breathing apparatus used by most mine rescue teams. A final demonstration project will be conducted during a mine rescue exercise.

Conclusion

Two advances in mine emergency communications have been achieved. Prototypes have been built and tested; however, further testing, repackaging, and improvements must occur before both devices are made available to the mining industry.

Improvements necessary to complete the SCSR communications system are: 1) improvements in the radio, 2) miniaturization of the electronics packages, and 3) the electronics package must be made permissible (intrinsically safe or explosion proof, to be allowed to operate in an explosive methane-air environment).

Improvements necessary to complete the life line communications system include: 1) choosing an optimal frequency for operation, 2) making a final selection on a quasi-leaky feeder cable, 3) choosing optimal interfaces for SCBA devices, and 4) making the system permissible.

This technology will significantly enhance the safety of mine rescue operations. It possesses the potential of allowing rescue teams to operate more efficiently. The combination of security and increased efficiency should also allow for the use of fewer teams in some circumstances thus further reducing exposure to very hazardous environments.