A Workplace Safety Device for Operators of Remote-Controlled Continuous Mining Machines

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INTRODUCTION

The focus of the National Institute for Occupational Safety and Health's (NIOSH) Pittsburgh Research Laboratory (PRL) is mining safety and health. Many of PRL's programs are instituted to satisfy needs that are identified through statistical evaluation of accidents and injuries. The Mine Safety and Health Administration (MSHA) is an agency that collects this type of data from the mining industry. The MSHA database shows there has been a high number of underground and surface personnel killed or permanently disabled as a result of working near machinery and powered haulage. Between 1991–1995, approximately 40 people per year were either killed or permanently disabled as a result of working near machinery, and there have been 40 or more people per year either killed or permanently disabled as a result of working near powered haulage. In addition, there were 4,658 days of work lost as a result of non-fatal injuries classified as ''working near machinery'', and there were 4,302 days of work lost as a result of non-fatal injuries near powered haulage. This represents 26% of 34,555 days lost in all mines. One location identified by MSHA to be particularly dangerous was in the general vicinity of the underground continuous coal mining machine (CM). MSHA requested PRL to study the problem and find a solution to reduce the risk of injury or death directly attributable to CMs. This report is a synopsis of PRL's efforts to date to resolve the man/machine proximity safety problem.

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METHODS

''Proximity Detection and Collision Avoidance'' (PDCA) was initiated to evaluate the task methods and procedures used by the CM operators, determine which areas around the CM are dangerous, and develop and/or identify devices that have the potential to minimize the hazards.

Most coal mines have a standard operating procedure (SOP) outlining CM operator positioning. However, there are times when a situation requires that the operator vary from the SOP. Previous research which examined the relationship between the SOP and the actual operator positioning [Love and Randolf, 1992], established a starting point for this project. The cited work established that ''Many mines have significantly increased safety and production by placing miner operators away from the hazards of unsupported roof using radio remote controlled CMs'' (Fig. 1). Because they have greater mobility, remote operators of CMs can see potentially critical areas of the work site that were not visible to an onboard operator. Remote operators, however, are more vulnerable and sometimes are unaware of how their position near the CM could cause them and/or their helpers harm.

The CM operator must perform a variety of tasks in operating a CM to produce coal. Each of these tasks has hazards and visual requirements. Researchers observed a number of operators with respect to their position and to their line of sight. Operators were also interviewed to determine what they felt were the requirements and hazards of operating the CM. All the data were summarized and compared to the SOPs. Forty-seven percent of the time, operators were observed in position not recommended in the SOP. While moving the machine, operators were observed outside the SOP position 31% of the time. Researchers concluded that the operator's position varied from the SOP primarily to satisfy the operator's need to be able see in

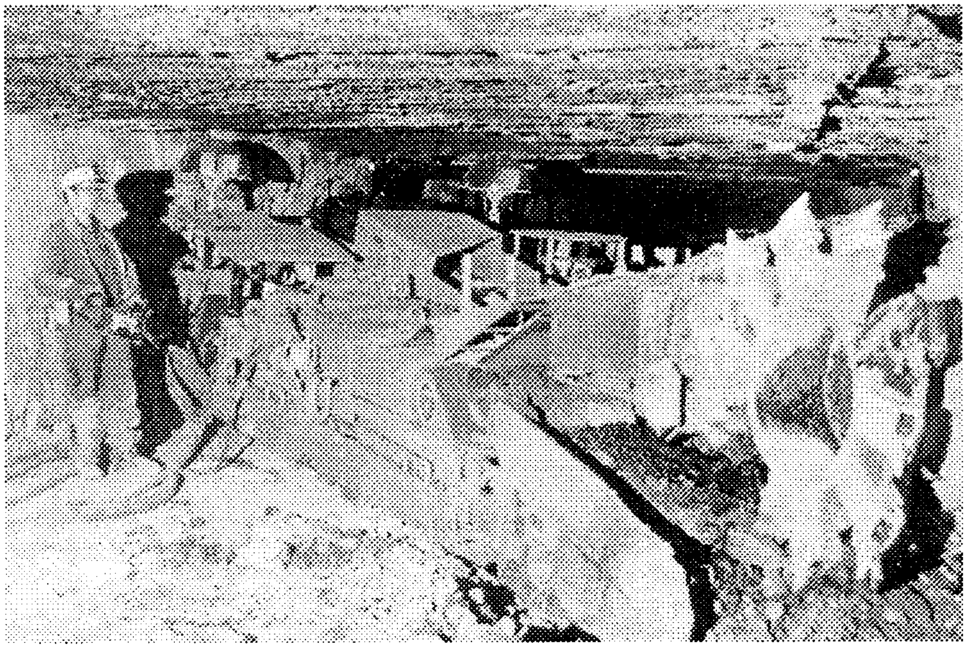

FIGURE 1. A typical remote controlled continuous mining machine.

order to perform the task. These were especially prevalent during the coal extraction phase.

Based on these findings, the PDCA team identified the need for a device that could alert CM operators when they stray into a hazardous working zone. The PDCA team established fundamental system design and functional requirements, which specify that the system shall:

1. Sense the presence of a miner in a known danger zone.
2. Provide some type of warning alarm and/or stop the CM when the operator is in a danger zone.
3. Must respond to people in close proximity to equally nearby inanimate objects.
4. Be simple to operate and maintain.
5. Be difficult to defeat, bypass, or disable.
6. Fail in a safe manner.

Investigation of many different commercially available technologies found none that could meet the performance specifications. The decision was made to design and build a system in-house, based on the use of low frequency magnetic fields. The concept is based on the fact that the strength of a low frequency magnetic field decreases as the cube of the distance from the source, in this case a current-carrying wire. Because the magnetic field strength diminishes so rapidly with distance, it is possible to shape a wire loop to define the contour of the danger zones which vary in size and shape with position about the machine. Thus, danger zones of the desired contour can be created by a combination of appropriately contouring the magnetic field source (wire), adjusting the current, and using a magnetic field detector with a fixed threshold. Based upon these concepts, a prototype system referred to as a Hazardous Area Signaling and Ranging Device (HASARD) was constructed.

It is important to emphasize that the HASARD is an active system. Two components are required: a field source and a detector, and both must be present. An active system was necessary, because the CM operates in close proximity to the coal seam and to other machinery as the normal consequence of harvesting coal. Many passive systems are not able to distinguish humans from other nearby objects. The drawback is obvious; a person must wear a HASARD receiver to be protected.

HASARD is a two-part system composed of a transmitter and one or more receivers, depending on the need. The transmitter is designed to be installed on-board the CM. The receiver is designed to be worn by the CM operator, the CM operator helper, and/or installed in the CM remote control pendant.

The HASARD transmitter consists of a low frequency current source whose outputs are split into several channels with independently adjustable amplitudes. Each channel is connected to a wire loop (antenna). Adjustments to the placement, shape, and current amplitude of each loop (Fig. 2) allow tailoring the magnetic field to conform to the shape and size of the danger zone for that part of the CM. When all current loops are located and adjusted properly, the danger zones for the machine are established and are approximated by a surface of constant magnetic field.

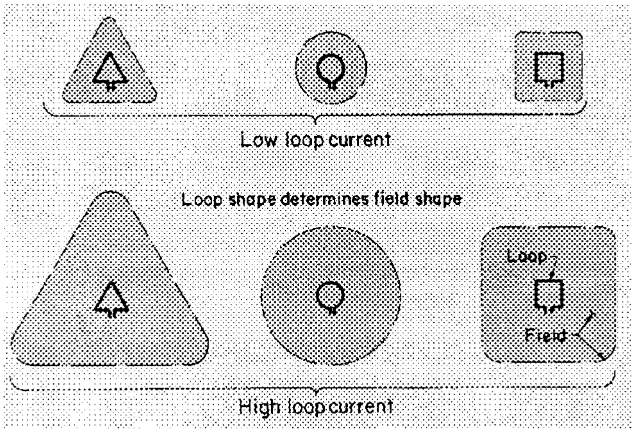

FIGURE 2. A small sample of the sizes and shapes of magnetic fields that can be produced.

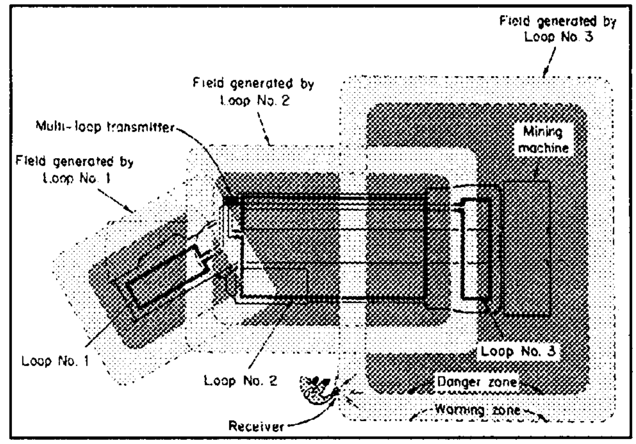

FIGURE 3. One example of the types of zones that can be created around a continuous mining machine.

The HASARD receiver is an omni-directional (direction independent) magnetic field strength meter. Multiple antennae detect the field, and the following electronics amplifies and filters the signal and converts it to a DC voltage level. This signal level is compared to thresholds which define the field strengths which represent areas of safety, caution, and danger (Fig. 3). Each threshold can be adjusted and affects the size (or the distance from the CM) of the danger and caution zones for the entire machine. The size of the protection zone for a particular or specific location is adjusted by adjusting the current to the appropriate current loop.

When a ''Warning'' or ''Danger'' lever is triggered, the receiver alerts the operator. It also can automatically disable CM functions, such as tramming or conveyor swing. The receiver has a variety of output indicators (e.g., visual, audible, and/or vibration). The indicators could be mounted inside the operator's hard hat or on the CM itself.

RESULTS

A prototype HASARD system was constructed, and it is being used to define critical design parameters. The HASARD system must function in the presence of electromagnetic noise produced by the CM electrical motors. Analysis of the electrical noise spectrum generated by a collection of CMs, performing a variety of tasks, revealed a heavy concentration of electrical noise below 15 kHz; above 15 kHz, the noise gradually decreased. Since the prototype was originally set at a frequency of 30 kHz, a decision was made to move the frequency of operation to 60 kHz to minimize interference problems.

Initial laboratory testing of HASARD using a CM and persons simulating mining activities will be followed by testing in PRL's Safety Research Coal Mine. If the tests are successful, additional underground trials will be conducted at a local cooperating mine.

CONCLUSIONS

NIOSH/PRL has designed a system which has the potential to improve the safety of CM operators and their helpers. Preliminary testing has shown that the concepts and the techniques employed appear workable. Planned underground tests will determine the viability of the whole system concept.

HASARD has shown potential for implementation beyond mining. Other uses could be at any workplace where people work in close proximity to machines, such as construction sites, agricultural, and warehouse operations.

REFERENCE

Love AC, Randolf RF. 1992. Continuous miner operators situate themselves for safety and better visibility. Coal Magazine 63–64.