MSHA PROXIMITY DETECTION

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Abstract
In order to address the large number of crushing and pinning type fatal accidents with the operation of remote control continuous mining machines, the Mine Safety and Health Administration (MSHA) initiated a program to pursue development of a tag-based, electromagnetic technology that can be deployed on mining machinery to alert miners who have breached the danger zone around operating machinery. This program took advantage of work performed by the National Institute for Occupational Safety and Health (NIOSH) which developed an active proximity warning system called HASARD (Hazardous Area Signaling and Ranging Device). The purpose of the system is to alert miners as they approach known dangerous areas around heavy mining equipment and other dangerous work zones. Two manufacturers have developed and obtained MSHA approval for electromagnetic, tag-based proximity detection systems. These systems have been tested on underground remote control continuous mining machines and proven to be reliable. The development and field testing history of these two systems is presented.

Introduction

Since the introduction of remote controls in the mid-1980s, the mining industry has experienced 31 crushing or pinning type fatal accidents associated with the operation of remote control continuous mining machines (see Figure 1). Remote controls offered increased safety and health benefits to continuous mining machine operators by removing them from the noise and dust exposure of on-board operation, but subject the operator to new crushing and pinning hazards.

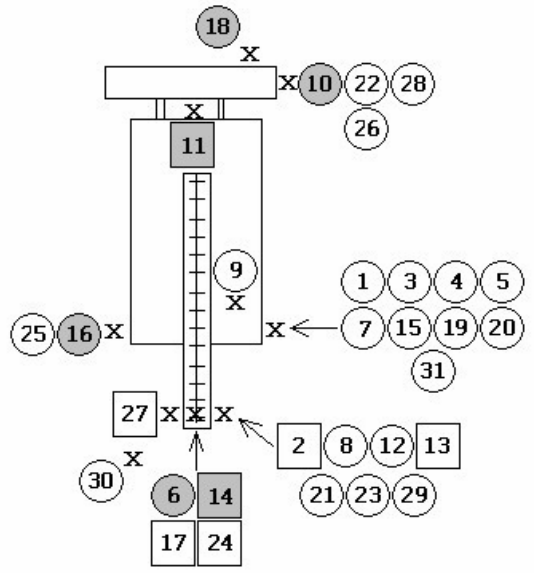

Figure 1 – Remote Miner Fatal Accidents

In the late 1990s, NIOSH established a technical project, Hazardous Area Signaling and Ranging Device (HASARD), to develop a system which could detect the presence of a miner within the hazardous operating area of a continuous mining machine. The result was a system consisting of a cable antenna installed around the perimeter of a continuous mining machine, which generates a local electromagnetic field, and a receiver/sensor worn by the miner, which measures the strength of the field and alerts the miner who wanders within the turning radius of a mining machine. NIOSH obtained Patent Nos. 5,939,986 and 6,810,383 for the HASARD system.

In an attempt to address a noted increase in the number of fatal accidents associated with the operation of remote control continuous mining machines, MSHA, in 2002, conducted a review of those fatality occurrences. The analysis of these accidents led MSHA to determine that proximity detection systems could prevent a large number of these type accidents. Subsequently, the agency developed these criteria: a proximity detection system should provide automatic proximity detection and machine shutdown to protect personnel from being run over, crushed or pinned when they are positioned in a hazardous area near the machine; the system should be capable of giving the operator an audible or visual warning when entering a protection zone before the machine shuts down; the system should consist of a personally worn electronic unit, on-board machine electronics and an antenna; and additional personnel may be protected if they are wearing an electronic unit.

MSHA undertook a special project to identify and investigate existing technologies providing proximity detection. MSHA partnered with two

manufacturers of the most promising of these technologies to develop a prototype proximity detection system and test it in an underground coal mine.

Technology Overview

Various proximity detection technologies were investigated for the remote control continuous mining machine application. The technologies investigated included ultrasonic, radar, infrared and tag-based systems. Ultrasonic and radar systems were excluded because they have difficulty discriminating between objects. Infrared technology for proximity detection was determined to be currently immature and in need of further development. The electromagnetic, tag-based technology offered the greatest potential for success on the specific remote control continuous mining machine application if certain obstacles could be overcome, such as interference from inductive coupling.

One of the major obstacles that MSHA dealt with in pursuing partnerships with proximity detection technology manufacturers was the limited size of the mining industry. Because of the limited opportunities with the underground coal mining industry, many major technology corporations are reluctant to enter the market. This limitation is evident in many aspects of safety technology development. The limited research funding available to the coal mine industry is typically devoted to the development of technologies that can increase productivity without adequate focus on safety enhancements. Two manufacturers, Nautilus International of Burnaby, BC, Canada and GeoSteering Mining Services of Huntsville, Alabama, agreed to partner with MSHA to test their system in an underground mining operation. Neither of these manufacturers received funding from the federal government or the industry. This proved to be an obstacle to the completion of the program.

MSHA pursued the development of partnerships for each manufacturer in order to provide assistance in adapting the technology to remote control continuous mining machines and to provide a field testing site. Massey Energy, who experienced a remote control continuous mining machine fatal accident at their operations in 2002, volunteered to work with MSHA to pursue development of proximity detection. Massey partnered with Nautilus International and originally offered the Rockhouse Energy Mine in Kentucky to field test the system; however, during the program, field testing was moved to their Spirit Mine in West Virginia. CONSOL Energy offered the Jones Fork Mine in Kentucky for field testing of the GeoSteering TramGuard™ proximity detection system. Since Jones Fork Mine and the Massey Energy mines used Joy Mining Machinery continuous mining machines, MSHA contacted Joy to request their assistance in adapting the proximity detection equipment to Joy machines.

Hence, each manufacturer was partnered with a mine operator that provided a site for field testing and with Joy.

Parameter Selection

One of the primary roles for MSHA in this program was assisting in determining the most appropriate technology parameters for the proximity detection systems. MSHA conducted a position study of the operation of remote control continuous mining machines at several mines in West Virginia to determine when proximity detection was most needed. This study concluded that proximity detection "should be activated while tramming in high or turbo speed and not be activated during production due to the operating location of the remote controlled continuous miner operator relative to the continuous miner." The study concluded that the operator often had to be positioned very near the machine for adequate vision while turning crosscuts. This was determined not to be detrimental to the effectiveness of the proposed technology due to the limited machine movement and therefore limited hazard exposure during this particular operation. The study further concluded that "proximity detection should be available around the entire machine during tramming" and "should be provided to others on the section who assist the continuous miner operator tram the miner."

Based on the position study conclusions and the relative location of the victims of fatal accidents, it was determined that MSHA's goal should be to provide proximity detection around the entire machine perimeter when tramming in high speeds. Proximity detection could be disabled during cutting and loading. Other section personnel should be protected in addition to the remote control continuous mining machine operator.

MSHA hosted discussions with the proximity detection manufacturers, the mine operator representatives, and representatives of Joy Mining Machinery to determine the best machine interactions. Included in these discussions were the relative advantages and disadvantages of having the proximity detection system de-energize the pump motor on the continuous mining machine versus having the system inhibit machine movement. Participants in these discussions expressed concern about potential wear on contactors exposed to frequent shutdowns and about production loss due to the time it takes to restart the machine. Also discussed was the possible use of a flashing light to warn the machine operator when he approached the shutdown zone. Various combinations of these parameters were used during different phases of the field testing with no ideal combination being identified.

Probably the most difficult determination of all has been identifying the ideal protection zone. (See Figure 2 for sample warning and shutdown fields.) This discussion inevitably becomes a tradeoff between optimal miner protection and practical operation of the system. While technologically it is relatively simple to provide a 10 foot protection zone around the entire machine, it is nearly impossible for a remote control continuous miner operator to adequately and safely perform all the necessary machine operation tasks while continuously positioned that far from the machine. Machine operators have expressed concern over the inability to properly set their sights when turning crosscuts from remote locations.

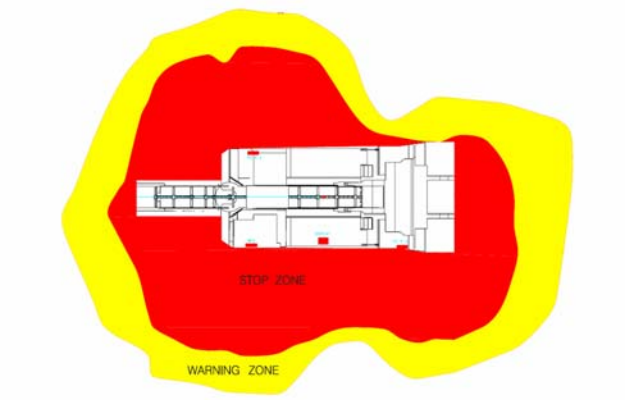

Figure 2 – Sample Warning and Stop Zones

In order to simplify the initial field tests, it was determined that the best combination of parameters should consist of:

- Protecting the right rear quadrant of the machine. This is because the majority of accidents occur in this quadrant.
- Providing a small field of protection when operating in low tram speed, and larger fields of protection when operating at higher speeds.
- Protecting only the machine operator.
- Interlocking the system with the cutter head to disable proximity detection while in cutting and loading mode.
- Providing a warning zone that when breached will cause the flashing light to turn on.
- Providing a shutdown zone that when breached will cause the continuous miner pump motor to de-energize. This disables all machine movement, including electric motor and hydraulic powered movement (conveyor movement).

It is recognized that these parameters will likely have to be modified when proximity detection is deployed in marketable form. The establishment of these parameters may prove to be the most difficult task in the finalization of proximity detection system specifications.

Discussion of Work to Date

Nautilus International

Nautilus International was identified as a likely candidate to supply suitable proximity detection equipment. Their Buddy System was successfully demonstrated at a Massey Energy repair shop on June 12, 2002. The Buddy System consistently provided warnings and machine shutdown at the distances set on the Nautilus Beltpack Unit (see Figure 3), when the machine was repeatedly trammed in reverse at turbo speed toward an operator positioned at the rear of the machine.

Figure 3 – Nautilus Beltpack

The first underground field test of the modified Buddy System occurred in June 2003. During this field testing, several significant problems were encountered that resulted in early suspension of the test. There were several system malfunctions, but more significantly, there was what appeared to be a calibration drift problem. This problem revealed itself in the gradual increase in required distance between the machine and the operator necessary to maintain machine operability.

Nautilus redesigned the system to address the assumed calibration drift. In July 2004, a second field test occurred using a significantly redesigned system with similar results. During this second field test, MSHA investigators discovered the specific problem was not calibration drift. They found that the signal produced by the on-board magnetic field-generating antenna was coupling onto the continuous mining machine's trailing cable resulting in an erroneous indication

of the operator's position. This phenomenon was referred to as inductive or parasitic signal coupling. The parasitic coupling problem proved very difficult to overcome because the frequency at which the Buddy System operated was an ideal frequency to permit signal coupling. Nautilus eventually overcame this problem during four additional field tests.

In late 2005, Nautilus introduced a significant revision to their system designed to overcome the parasitic coupling issue. The field generating antenna (see Figure 4) had been significantly redesigned such that 360˚ of protection around the machine was provided by a single centrally mounted intrinsically safe antenna. This modified system was successfully field tested in April 2006.

Figure 4– Nautilus Antenna

The system tested in April 2006 was installed to inhibit the machine tramming function and to activate a flashing light when the warning zone was breached. The system would de-energize the pump motor when the shutdown zone was breached. The system provided two different protection zones for low and high speed operation. Proximity detection was disabled when the cutter motors were energized. Only one electronic unit worn by the machine operator was tested.

The testing results of the revised Nautilus proximity detection system at the Spirit Mine in April 2006 showed:

- One antenna positioned near the middle of the machine provided protection for the operator side of the machine and the opposite operator side of the machine except for the left front corner of the machine.
- The protection zones around the machine remained constant throughout the test.
- There was still some parasitic coupling on the trailing cable and water hose, but this coupling appeared minimal and did not have a negative impact on the operation of the system.

- The beltpacks would occasionally lock-up and have to be auto-tuned and re-calibrated.

MSHA issued an approval for compliance to Title 30 Code of Federal Regulations (30 CFR) Part 18 for the Nautilus Coal Buddy Proximity Detection System in July 2006.

GeoSteering Mining Services

GeoSteering Mining Services, LLC from Huntsville, AL, initiated its own proximity detection design effort in November 2004. They purchased the license for the NIOSH HASARD system. GeoSteering partnered with Gamma Services International, Inc. and developed the TramGuard™ proximity detection system. This system made use of several machine-mounted field generators (see Figure 5) housed in explosion-proof enclosures to generate the protection zone around the machine. A protection zone, generated by strategically locating the field generators, could prevent the majority of crushing/pinning type remote control continuous mining machine accidents.

Figure 5 – Geosteering Field Generator

Only the right side of the machine was protected in the TramGuard™ field tests through use of three machine-mounted field generators, one mounted on the conveyor boom, one mounted on the right rear of the machine frame, and one mounted on the right front of the machine frame. No warning light was used. The system was designed to inhibit tram movement when the warning zone was breached and de-energize the pump motor when the shutdown zone was breached. Proximity detection was disabled when the cutter motors were energized. Only one personal alarm device (PAD) worn by the machine operator was tested (see Figure 6).

Figure 6 – Geosteering PAD

The system provided consistent warning and shutdown commands in its initial field testing at CONSOL Energy's Jones Fork Mine in Kentucky in November of 2005. It was effective in preventing the machine operator from entering the hazardous area around the machine.

The testing of the TramGuard™ proximity detection system at the Jones Fork Mine in November 2005 showed:

- Three field generators mounted on the machine provided protection of the right (operator) side of the continuous mining machine except for the front of the cutter head.
- The operator side protection zones remained constant through the tests.
- The combination of the fields from the field generators provided expanded coverage to the operator side of the machine often forcing the operator to undesirable distances from the machine.
- No significant occurrence of parasitic coupling was noted.

MSHA issued an approval for compliance to 30 CFR Part 18 for the GeoSteering TramGuard™ Proximity Detection System in January 2006.

Matrix Design Group M3-1000 Proximity Detection System

Matrix Design Group submitted an application to MSHA in late 2007 for approval of their M3-1000 Proximity Detection System. This system reportedly uses a different approach. While it uses the electromagnetic, tag-based technology as the two aforementioned systems, the person-worn component actually provides the field, and the machine mounted components act as the receiver. As of this writing, the system has not yet been fully approved by MSHA nor has an operable system been witnessed by MSHA personnel.

Future Work

The primary focus for future MSHA proximity detection efforts will be application specific implementation issues as well as promotional endeavors. We plan to work with NIOSH as well as state agencies to pursue future proximity detection technology development efforts and will continue to assist manufacturers of proximity detection technology to tailor their designs to specific applications and to obtain the necessary MSHA approvals. MSHA will work directly with individual mine operators and their representatives to assist in implementation of proximity detection.

Summary

Proximity detection technology has the potential to dramatically improve the safety of mining operations in many different areas. In addition to the remote control continuous mining machine application, proximity detection also has the potential to reduce accidents associated with the use of underground mining machinery such as shuttle cars, scoops and conveyors. This technology has proven suitable for application to surface haulage equipment to protect against large vehicles colliding with other vehicles or pedestrians. Proximity detection is currently being evaluated to warn of overhead high voltage lines. It could be applied to dump points to warn machine operators when they approach the stopping point. MSHA recently conducted a review of all mining-related fatal accidents from the last five years. It was determined that approximately 20% of all mining-related deaths could be prevented through the use of proximity detection.

Acknowledgements

This program would not have been successful without the dedicated contributions of many parties. Foremost among the contributors were the highly involved representatives of Massey Energy and CONSOL Energy. In addition, several representatives of Joy Mining Machinery were instrumental in completion of this project. The following MSHA, Approval and Certification Center personnel are also gratefully acknowledged for their contributions: Jerry Dransite, Kevin Dolinar, Patrick Retzer, Ken Porter, Chad Huntley and Robert Holubeck.

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