DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
1090 Tusculum Avenue
Cincinnati, OH 45226-1998

DEC 15 2015

December 15, 2015

MSHA
Office of Standards, Regulations, and Variances
201 12th Street South
Suite 4E401
Arlington, Virginia 22209-3939

Docket No. MSHA-2014-0019

Dear Sir/Madam:

The National Institute for Occupational Safety and Health (NIOSH) has reviewed the Mine Safety and Health (MSHA) Proposed Rule on *Proximity Detection Systems for Mobile Machines in Underground Mines* published in the *Federal Register* on September 2, 2015 [80 FR 53070]. Our comments are enclosed.

Please do not hesitate to contact me at 513/533-8302 if I can be of further assistance.

Sincerely yours,

Paul A. Schulte

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Director
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Enclosure

AB78-COMM-19

National Institute for Occupational Safety and Health

NIOSH®

Comments to MSHA

Comments of the National Institute for Occupational Safety and Health on the Mine Safety and Health Administration Proposed Rule (PR) on Proximity Detection Systems for Mobile Machines in Underground Mines

[Docket No. MSHA—2014—0019]

RIN 1218—AB78

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Cincinnati, Ohio

December 15, 2015

The National Institute for Occupational Safety and Health (NIOSH) has reviewed the Mine Safety and Health Administration (MSHA) proposed rule (PR) *Proximity Detection Systems for Mobile Machines in Underground Mines* published in the *Federal Register* on September 2, 2015 [80 FR 53070]. As noted in the PR, NIOSH maintains and updates a web page describing research on proximity detection systems and technology: http://www.cdc.gov/niosh/mining/topics/ProximityDetection.html. NIOSH continues to conduct research to improve the performance of proximity detection systems to prevent injuries involving powered machinery in mines. NIOSH supports the MSHA effort to reduce potential pinning, crushing, or striking accidents in underground coal mines and offers the following comments.

Page 53071: "*MSHA has evaluated all accident reports involving coal hauling machines and scoops between 1984 and 2014. MSHA has determined that a proximity detection system could have prevented 42 fatalities and 179 injuries resulting from these accidents that occurred on the working section.*"

Comment: NIOSH agrees that proximity detection systems could prevent fatalities and injuries. NIOSH analyzed the causes of fatalities reported to MSHA (http://www.msha.gov/fatals/coal/2015/) for the five-year period 2009-2013 [Burgess-Limerick and Steiner 2015]. Twenty-two of the 84 fatalities in underground coal mines and two of the 15 fatalities in underground metal mines may have benefitted from a properly designed proximity detection system. Although design or usability of the systems may differ for different equipment, proximity detection could substantially reduce fatalities and injuries. (The data are summarized in the appendix to these comments.) Additional analyses are currently being performed for years 2005 thru 2008 and year 2014.

Page 53074, second column: "*MSHA solicits comments on other types of mobile machines that should be required to be equipped with proximity detection systems. MSHA specifically solicits comments on circumstances where it may be appropriate to require loading machines, roof bolting machines, and feeder breakers to be equipped with a proximity detection system.*"

Comment: NIOSH research has focused on the use of proximity detection systems on continuous mining machines (CMMs) and factors influencing their performance in underground coal mines [Jobes et al. 2011a,b; Carr et al. 2013]. Although few research studies have investigated how these factors may influence proximity detection systems on other mining equipment including mobile haulage, loading machines, roof bolting machines and feeder breakers equipment, it is possible that similar issues and limitations will exist with technologies such as electromagnetic-based proximity detection systems on these systems. Research is currently being conducted by NIOSH on the application of proximity detection technologies for different types of underground coal mining equipment that could potentially benefit from these systems.

Page 53075, first paragraph: "*MSHA considers coal hauling machines and scoops to be equipped with a proximity detection system when the machine-mounted components are installed on the machine and miners are provided with the miner-wearable components.*"

Comment: NIOSH recommends specific requirements for these systems, based on criteria prescribed by MSHA, to be considered the minimum functional requirements of the machine. For example, criteria could be developed for repeatability and reliability of the systems by establishing baselines for detection zones and ensuring proper functionality when multiple wearable devices are within a detection zone. Parameters and examples of practical testing to ensure functionality of proximity detection systems for CMMs are described in Carr et al. [2014, 2015].

Page 53076, first paragraph: "*MSHA solicits comments on the proposed training for miners who operate or work near machines equipped with proximity detection systems.*"

Comment: NIOSH studies have shown an in-depth view of mine workers' perspectives and how their job tasks and environment could be or are affected when learning to use new technology. Specifically, gaining an in-depth view of mine workers' perspectives and how their job tasks and environment could be or are affected and then incorporating that information into training may help to prevent accidents and injuries that have been labeled as human error in the workplace [Haas and Rost 2015]. Studies of CMM operators have found that unintended consequences, such as a disruption in situation awareness, risks, hazards, and decision-making capabilities, can be avoided if human factors considerations are integrated into each stage of the technology design and implementation process [Horberry et al. 2015; National Research Council 2013]. These human factors considerations should be part of the operation training of each specific piece of equipment utilizing proximity detection systems. New task and equipment training on the function and operation of proximity detection systems are necessary during implementation. However, further research is needed to determine the most effective training methods, as well as the possibility of a standardized training method and implementation plan, for all proximity detection systems. Each piece of equipment needs to have a uniquely prescribed proximity system; the proximity systems for some types of equipment will be more complex than others. The methods and amounts of training for each system should be designed specifically for each system and common platforms established where possible. Formative research utilizing surveys and in-depth interviews will be conducted by NIOSH with mobile equipment operators, mechanics, and mine management to investigate risk perceptions related to using and interacting with proximity systems

Page 53076, third column, first paragraph: "*MSHA solicits comments on whether the Agency should require that miners wear reflective material to make them more visible to equipment operators and, if so, how much and where.*" Page 53076, second column, last paragraph: "*Existing §75.1719-4(d) requires that each person who goes underground in a coal mine wear a hard hat or hard cap with a minimum of six square inches of reflecting tape or equivalent paint or material on each side and back.*"

Comment: Properly designed reflective material may make miners more visible. The reflective material type (there are multiple types, each designed for a specific application), amount, and location that would provide adequate visibility are unknown and further research is needed. Standards currently exist for making workers more visible through use of reflective materials [ANSI 2010; CSA Group 2014]. Some mines are using these standards as a basis for purchasing reflective clothing for miners; however, it is unknown if these standards are effective for mining as the mining environment is very different than the environments used as a basis for developing these standards and workers are near each other in a confined environment. Further research is needed to determine the type of reflective material, color, placement, and surface area of material that will enable the reflective material to be effectively visible to miners. Excessive amounts of reflective materials could present a safety hazard from excessive glare to nearby workers. We are not aware that reflective materials have been implicated in mining accidents; however, we have received several inquiries from miners concerning the extreme glare from excessive use of reflective materials on clothing.

Page 53076, third column, second paragraph: "*MSHA intends that the proximity detection system would stop all movement of the machine, such as tramming, conveyor chain movement, and raising or lowering the bucket of a scoop that could cause the machine to contact a miner. The machine would remain stopped while any miner is within a programmed stop zone.*"

Comment: The MSHA PR requires that proximity detection systems would stop all machine movement. Under the PR, any proximity system incorporating selective shutdown would not be permitted. This proposed requirement by MSHA would potentially limit the development and application of advanced technology for selective shutdown features. For example, NIOSH developed intelligent proximity detection technology that inhibits only machine functions that could cause striking or pinning while allowing other machine functions to continue [Ducarme et al. 2015]. The MSHA CMM rule is performance-based and does not require the proximity detection system to stop all machine movement; it requires only that the proximity system prevent the machine from contact with mine workers. NIOSH recommends the mobile rule be worded similarly.

Proximity detection systems have been emerging in the mining industry as a useful tool to predict and prevent collisions between one piece of mobile equipment and another, or between a piece of mobile equipment and a person. NIOSH developed electromagnetic proximity detection technology about ten years ago as the Hazardous Area Signaling and Ranging Device (HASARD) [Schiffbauer 2002]. This system used an electromagnetic field generator to create a magnetic field measurable by a wearable Personal Alarm Device (PAD). The PAD's measurement of the field strength gives a rough indication of the distance between the generator and the PAD. Several manufacturers adopted the concepts developed with HASARD and further refined the technology. Electromagnetic-based systems are now commercially available to the mining industry. The currently available systems are not capable of providing the level of protection required in the industry while maintaining the operator's freedom to efficiently perform the job [Haas and Rost 2015]. To be acceptable to the miners and to avoid false alarms, a proximity detection system must provide the necessary protection while still allowing normal operation of the machine. An intelligent system that can make decisions based on situation-specific conditions is necessary [Carr and DuCarme 2013]. MSHA regulations should enable the mining industry to develop new technologies and offer protections such as selective shutdown of machine movements while still providing the safety requirements of a proximity detection system. NIOSH recommends that the final rule for mobile proximity detection systems be performance-based and require that the proximity system prevent the machine from contact with mine workers.

Page 53077, first column, last paragraph: "*MSHA solicits comments on whether to require a proximity detection system to cause the machine to slow before causing it to stop and, if so, what requirement would be appropriate. MSHA also solicits comments on effective methods or controls, working in conjunction with the proximity detection system, to protect the on-board operator from sudden stops. MSHA also requests comments on what types of machine movement the proximity detection system should stop, beyond movement related to tramming coal hauling machines and scoops.*"

Comment: NIOSH field tests of proximity systems on CMMs and input from stakeholders found that detection range, environmental effects/limitations, detection accuracy, and system repeatability are considered critical parameters [Carr et al. 2014, 2015]. Current NIOSH research is identifying critical parameters that impact the performance of mobile proximity systems such as stopping distance and deceleration rates.

Page 53077, second column, last paragraph: "*MSHA solicits comments on how the use of proximity detection systems and the overlap of protection zones on multiple types of machines operating on the same working section might affect miners' work positions, such as a continuous mining machine operator who may need to work close to the continuous mining machine when cutting coal or rock.*"

Comment: NIOSH will be conducting field evaluations in 2016 on proximity detection system performance for underground mobile coal haulage equipment. These field evaluations will evaluate proximity systems and show the capabilities of existing systems, as implemented. These tests will evaluate real-world scenarios such as how a proximity system would have to detect multiple stationary or moving miners located in the entry or out of sight. Results of these field evaluations will give industry a better understanding of the parameters needed to protect mine workers using multiple proximity systems. NIOSH is also investigating this problem with a human systems integration approach similar to the approach to enhancing mine escape capability suggested in a recent National Academies of Science Report [National Research Council 2013]. Specific knowledge of tasks performed around all equipment and the interaction of proximity systems need to be studied to ensure effective design and usability of the system [Horberry et al. 2015; National Research Council 2013].

Page 53078, first column, last paragraph: "*MSHA solicits comments on the proposed requirement that the proximity detection system provide audible and visual warning signals on miner-wearable components and a visual warning signal on the mobile machines.*"

Comment: Underground mobile mining machines pose a difficult safety challenge because their operators work in close proximity to the machines in very restricted spaces. NIOSH has conducted research on the development and use of a visual warning system [Sammarco et al. 2012] to generate several lighting sequence scenarios where human subject tests evaluated their effectiveness using a computer-based multimedia platform. An unobstructed visual signal is preferable to an audible signal for providing feedback to miners because a visual signal cannot be obscured by ambient noise. The test results indicated that a "fast flash" visual warning is the most effective based upon subject preference, rating, and accuracy of proximity intrusion location identification. This arrangement improved reaction time by 35% [Jobes et al. 2013].

Secondly, a warning needs to be associated with a specific location of a hazard; thus, a visual warning would be more advantageous on the machine than an audible one [Sanders and McCormick 1993]. Additionally, audible warnings may not be effective because of the ambient noise and reactions to visual signals are generally faster than those to auditory signals [Campbell et al. 2007]. However, the warning light should be within 30 degrees of the operator's normal line of sight; thus, the efficacy of the visual warning is dependent on the placement of the wearable component [Sanders and McCormick 1993]. When considering auditory and visual spatial stimulus response situations where the response is directly related to the stimulus location, reactions to visual signals are generally faster than those for auditory signals [Lee and Chan 2007]. It should also be noted that a visual warning can often be obscured and haptic warnings (such as vibration feedback) would be an appropriate part of a redundant warning system [Campbell et al. 2007].

Page 53078, second column, first paragraph: "*MSHA solicits comments on whether requiring audible warning signals in addition to visual warning signals on the machine would help assure that miners, including the machine operator, know that a miner is in the warning zone and the machine is about to stop.*"

Comment: The benefits of having both an audible and visual warning are unknown, specifically in this underground mining situation. The audible warning will provide little if any benefit given that it would be difficult to hear because mine workers wear hearing protection to protect them from the hazardous noise of the mining environment. Secondly, 25% of mine workers have a severe hearing problem and 80% have a hearing impairment by the time they reach retirement age [NIOSH 2015]. Lastly, even if miners could hear the audible warning, there would be no clear benefit compared to a visual warning given reactions to visual signals are generally faster than those for auditory signals [Lee and Chan

2007]. Therefore, considerations for redundant warning signals may include combinations of visual, audible and/or haptic signals [Campbell et al. 2007].

Page 53078, second column, first paragraph: "*MSHA also solicits comments on whether requiring the use of a specific visual warning on the machine, e.g., strobe lights, clustered light-emitting diode (LED) lights, or other types of visual signals, would help assure that the visual warning alerts miners near the machine, including the machine operator.*"

Comment: A visual warning on the machine that would ensure high visibility and reliability could help to alert miners. Visible warnings can be effective and their effectiveness has been quantified [Sammarco et al. 2012; Jobes et al. 2013; Sanders and McCormick 1993; Lee and Chan 2007]. Reactions to visual signals are generally faster than those to auditory signals [Campbell et al. 2007] which would help miners respond faster.

NIOSH recommends that MSHA specify functional performance requirements of the light source and to not specify a particular lighting technology. For example, light-emitting diodes (LEDs) have many advantages compared to other light sources including a potential service life of up to 50,000 hours, but only if they are designed properly. An LED could fail in less than one hour if thermal management of the LED, as mounted in a lighting fixture, is inadequate, or the light output can decrease significantly if the thermal management is inadequate [Sammarco et al. 2009]. Thus, usable service life is an important performance requirement. Reliability is also an important performance requirement because miners could be in an unsafe position and unaware that the visual warning is not working. Visibility of the warning light by miners located at various positions about the machine is important. Flash rate is also an important functional performance item. A 4 Hertz (Hz) flash rate is most effective. Lastly, color is important so MSHA should specify the color(s) so that high visibility is enabled and color consistency exists among various warning systems [Sammarco et al. 2012; Chan and Ng 2009; Wierwille et al. 2006].

Page 53078, second column, second paragraph and third column, first paragraph: *Proposed § 75.1733(b)(3) would require that a proximity detection system provide a visual signal on the machine that indicates the machine-mounted components are functioning properly.... MSHA solicits comments on the proposed requirement.*

Comment: A properly designed visual indication that the visual warning system is functioning properly on the machine might be of benefit to miners. One example of an improper design would be that of turning on the visual indication light because electrical power is being supplied to the visual warning system. This only indicates electrical power is being supplied and does not verify that system's hardware and software are operating correctly.

Current NIOSH research is investigating the design parameters, including functional components, for proximity detection systems on mobile haulage equipment that provide optimum protection for underground workers. Results will determine the requirements of a visual signal to indicate machine-mounted functionality.

Page 53079, first column second paragraph: "*MSHA requests comments addressing whether requiring both an audible and visual warning signal is needed to assure that all miners on the working section know that the machine-mounted component is not functioning properly.*"

Comment: Visible warnings are effective and their effectiveness has been quantified [Sammarco et al. 2012; Jobes et al. 2013; Sanders and McCormick 1993; Lee and Chan 2007]. Reactions to visual signals are generally faster than those to auditory signals [Campbell et al. 2007]. The effectiveness of adding audible warnings to visual warning in a mining environment is unknown. It is logical that audible warnings may not be effective because of ambient noise in the highly mechanized environment of underground mining operations where one out of every four miners has a severe hearing problem and 76% of mine workers are exposed to hazardous noise, the highest prevalence of all major industries [NIOSH 2015]. Also, NIOSH recommends that MSHA require redundant systems that incorporate two or more different warning signals; the system should be demonstrated by research that they are effective under the mining scenarios in which they will be implemented. A visual warning can often be obscured and haptic warnings (such as vibration feedback) could be an appropriate part of a redundant warning system [Campbell et al. 2007].

Appendix

Summary of results for 2009-2013 fatalities:

Underground coal:
7 – Interlocked Proximity detection for CMM (2010-33, 2010-39, 2011-04, 2012-12, 2012-16, 2012-17, 2013-04)
4 – Interlocked proximity detection fitted to shuttle car (2010-36, 2010-40, 2010-46, 2013-18)
3 – Interlocked proximity detection fitted to scoop (2012-18, 2012-13, 2013-06)
2 – Interlocked proximity detection on conveyor (2011-01, 2013-09)
1 – Interlocked proximity detection on hoist (2013-03)
1 – Interlocked proximity detection on personnel carrier (2011-20)
1 – Interlocked proximity detection – brakeman car, locomotive, loaded rail car (2009-14)
1 – Interlocked proximity detection – battery powered coal hauler (2013-10)
1 – Interlocked proximity detection installed on RAM car (2010-41)
1 – Interlocked pedestrian proximity detection (2012-14)

Metal underground:
1 – Interlocked proximity detection – (2009-11) "Victim was looking into loader bucket to look for hydraulic leak when he was struck by the ejector plate"
1 – Interlocked edge proximity detection (2013-08) "LHD being used to build berm traveled over edge of stope and fell into hole"

Commodity	Location	Fatalities
Coal	Surface	27
	Surface at underground	15
	Underground	84
Metal	Surface	10
	Underground	15
Non-metal	Surface	13
	Underground	3
Stone	Surface	29
	Underground	5
Sand and gravel	Surface	19

Reference: Burgess-Limerick R, Steiner L [2015] using MSHA reports at http://www.msha.gov/fatals/coal/2015/. Analyses of 2005–2008 and 2014 reports will be conducted.

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