EXPERIMENTAL TRAINING TO REDUCE VARIABILITY IN THE INTERPRETATION AND APPLICATION OF MACHINE GUARDING REQUIREMENTS

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ABSTRACT

The use of machine guards for industrial equipment is commonly accepted as a primary means of injury prevention. Often the interpretations of rules pertaining to machine guarding lead to a variety of guarding applications at the worksite. The consequences of this variability between regulatory intent and practice are evidenced by the frequency of guarding citations by inspectors, litigation seeking to ameliorate judgment of the inspectors, injuries that may be sustained because of workers' misunderstanding of safe guarding practices, misinterpretations of guarding requirements, or failure to comply with guarding mandates.

Training is a common method used for reducing this variability. This paper describes a U.S. Bureau of Mines-developed training intervention that might begin to define and identify this variability within the inspectorate, work force, or management. The fidelity of the training is enhanced through the use of three-dimensional slides and the structure of the classroom exercise. The classroom simulation moves beyond traditional safety training by offering an opportunity to apply general guarding rules and regulations to a specific situation. It is suggested that this type of training may be useful in defining and seeking solutions to the apparent variability in both the interpretation and application of guarding requirements.

INTRODUCTION

The reason behind a machine guard seems simple enough—to prevent employees from coming in contact with moving parts. The method of providing that protection appears equally simple—install a barrier. Machine guarding is not a new concept. The first patent issued for a machine guard was registered in 1868 (*1*).[3] Since then, the guarding of moving parts has become much more sophisticated. A major influence on present machine guarding practices was the Occupational Safety and Health Act of 1970 (OSHAct) (*2*). Within a few years of the OSHAct, the National Safety Council asserted: "One of the major goals of the [Act] is the guarding of all machinery and equipment to eliminate personnel hazards created by point of operations, in-going nip points, rotating parts, flying chips and sparks. These hazards have been responsible for countless numbers of injuries, and fatalities of personnel. **If the now required guarding had been required back then** [prior to the OSHAct], many if not most of these accidents might have never occurred and even . . . **[the Act itself] would probably not be the law of the land**" (*3*). These remarks imply a widely accepted recognition of the importance and application of machine guarding requirements.

What can be done today to better apply a proven technique for loss prevention? While the solution may be elusive, the U.S. Bureau of Mines (USBM) conducted this research to learn more about the sources of variability

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[3]Italic numbers in parentheses refer to items in the list of references at the end of this paper.

between guarding theories, regulations, and everyday practice. This approach would involve the collection of data. These data could define the variability within the inspectorate, management, and work force concerning the practical understanding and application of guarding requirements. Defining variability, through structured training experiments, may lead to a shift in the way one thinks about traditional safety training. These "training experiments," in defining variability, may lead to innovations in guarding practices, work procedures, and training protocols. Benefits could include a further reduction in the number of injuries related to improper guarding practices, reduced levels of violations, and lesser reliance on the judicial system to resolve a variety of interpretations of machine guarding regulations.

EVIDENCE OF VARIABILITY

Although the sensible notion of "good guarding practices" is fairly common within general industry, other factors suggest that variability exists in the regulatory interpretation and use of machine guards at the workplace. How can this variability be described? Does it fall within the literature relating to perception and recognition, motivation, judgment and decisionmaking, ergonomic design, or the adherence of workers to safe job procedures? Understanding and describing this variability may offer insight to solutions that embody all these concepts. This knowledge could assist in the design of training, the design of guarding components, or regulatory policy. The evidence of variability is manifested by the information obtained from injury reports, legal controversies, and violations-citations associated with machine guarding practices.

INJURY DATA

One important consequence of variability between regulatory intent and practice is the frequency of serious injuries. A variety of questions might be posed based on any one of these incidents. To illustrate, in 1993, a beltman was fatally injured while cleaning an area around an underground belt drive. The U.S. Mine Safety and Health Administration (MSHA) investigative report (*4*) notes:

> A beltman was fatally injured when he partially removed a guard from the side of a stationary roller and entered the take-up area with the belt in motion. Guarding for the belt and take-up assembly was constructed with four foot wide by eight foot long sheets of expanded metal welded in angle iron frames and bolted onto a main frame. The guarding was then secured to the entire length of the drive and take-up assembly on both sides. Evidence indicated that the victim partially removed the stationary guard in an attempt to gain access to the take-up area. While shoveling loose coal, he became caught in the roller and was fatally injured.

Assuming the guard was "adequate" prior to its removal, what are some questions that might be asked to explore the contributing factors?

1. Was there an appropriate machine guarding policy at the mine?
2. How was the employee trained? Were there any follow-up observations of his performance?
3. Was there a lockout-tagout procedure?
4. Was the hazard recognizable?
5. Was this a safe practice?

Responses to these questions highlight variability. These include perceptions of what constitutes (1) an *appropriate* policy, (2) *quality* training, (3) an *adequate* procedure, (4) a *recognizable* hazard, and (5) a *safe* practice. These perceptions would be expected to vary within and across the inspectorate, work force, and management.

Outside of mining, the importance of researching these questions is magnified. For example, within the agricultural sector, Etherton (*5*) estimates that 20,000 occupational amputations occur annually. Ninety percent of these serious injuries are traced to machinery and equipment. The magnitude and severity of these injuries amplify the need to pose serious questions. The careful consideration of these questions might lead to a better understanding of the variability between regulatory intent and everyday practice.

LITIGATION

Another indication of variability is perhaps evident in the number of legal controversies surrounding safe or unsafe guarding practices. In more than a few cases, the final determination of "compliance" with guarding regulations is a product of the judicial system. In one case, involving a piece of mobile equipment, it was determined that failure to properly guard the cooling fan blades and air compressor belts and pulleys located on the front of the engine was a valid violation. The parts in question were located in the center of the engine compartment in front of the engine. In order for an individual to contact the parts, it would be necessary to reach over the truck frame, which is approximately 76.20 cm high, and extend one's arm a distance of approximately 76.20 to 91.44 cm. The judge ruled that "given the physical accessibility of the engine compartment, the fact that mechanics could check and work on running equipment, and that contact with the cited machine parts could occur, we conclude that a reasonable possibility of contact existed" (*6*). In litigation, variability is exhibited by the opposing views of those involved in the case.

VIOLATION AND CITATION DATA

Violation and citation data may also imply large levels of variability within and across the inspectorate, general work force, and management. In 1991, for general industry, OSHA reported over 4,000 violations issued for unsafe machine guarding practices, with an initial dollar penalty of $6.64 million (*7*). The direct costs resulting from citations of unsafe machine guarding ranked third, behind hazard communication and electrical lockout-tagout procedures.

A review of MSHA data indicated that from 1991 through 1993 there were 20,517 significant and substantial violations issued for unsafe guarding practices in the mining industry (*8*). These numbers may be directly linked to the undefined variability that surrounds safe guarding practices.

How one interprets machine guarding regulations, how one determines if a guard is adequate (or, in compliance with the regulations), how one maintains or modifies a guard, or how one adheres to safe guarding practices can all contribute to large levels of variability.

For the regulators, the violation data explicitly imply variability in compliance profiles. Implicitly, is the issue one of adherence (motivation and skills)? Is it one of how workers and managers interpret the regulations? Or, a combination of both? Knowledge does not guarantee a decision to act, nor does it obligate the appropriate action. What can be learned from studies of traditional mine safety training that could offer insight to these questions?

TRADITIONAL METHODS FOR MINE SAFETY TRAINING

Safety training is a common method to inform and motivate workers to adhere to safety procedures and requirements. Its widespread acceptance to loss prevention is ingrained within regulations, company policies, and culture of the workplace. Training implies increased competence; competence suggests some means to measure; and measurement implies a connection between the training intervention and goals of the organization. Improved competence, in turn, cannot be defined without some means of evaluation. The concept of training (and performance) evaluation is consequential, as it suggests a means for improvement.

USBM-sponsored studies of mine safety training were described in a series of research reports by Adkins (*9*), Digman (*10*), Short, (*11*), and Cole (*12*) spanning the period of 1976 to 1986. These evaluative studies of mine safety training, coupled with the general safety training literature, offer insight into methods to understand the limitations of traditional safety training. Combined, these studies suggest a shift to instructional procedures that can better tie investments in training to the performance of the workforce. Performance measures imply a reliable means to evaluate, both within the context of the training and how those skills are transferred to the worksite.

Two of the more recent studies (*10, 12*) observed a noticeable level of variability in both the conduct and outcomes of classroom health and safety training. This variability was observed during annual refresher training sessions. Researchers noted several of the reasons for this variability:

1. There was confusion among the trainers and participants concerning the expected outcomes of safety training.
2. There is limited availability of good test designs to assess health and safety knowledge and the application of that knowledge.
3. Miners were more attentive when participation was encouraged or instructors used stories or examples to ground the instruction.
4. The preponderance of concern was more apt to relate to quantity of instruction (i.e., hours of training) as opposed to outcomes (quality).
5. The use of innovative teaching techniques (games or simulations) was fairly common but usually limited to the factual recall of safety information.
6. Trainees appeared most attentive when discussions involved the resolution of a safety problem in a work procedure or emergency protocol.

These studies suggest that traditional mine safety training could benefit by more objective and reliable data. These data would better connect safety training interventions to the performance of the work force. It is within this context that the following training exercise was developed.

A NEW APPROACH

The "Raggs and Curly" machine guarding exercise is a three-dimensional (3-D) latent image simulation.[4] The idea of combining 3-D slides with latent image simulation was first introduced in 1989 (*13-14*). The Raggs and Curly exercise embeds teaching with evaluation, makes use of 3-D slides to enhance the fidelity of the simulation, and is administered in small group settings. It is similar in structure and complements the growing set of interactive, latent-image, problem-solving simulations described elsewhere (*e.g., 12, 15*).

Raggs and Curly is an eight-question, seven-slide exercise that deals with machine guarding hazards and unsafe practices. The Raggs and Curly exercise is set at a surface coal mine. The situation is as follows:

> You, Earl E. Raggs, are the chief mechanic at the main mine complex of the AB Coal Company. You have been called to the Jake's Run surface mine. The mine supplies coal directly to rail cars by means of a 48" mobile conveyor. The superintendent explains that during a recent insurance company inspection, some potentially dangerous situations concerning improper guarding practices were noticed. He instructs you to conduct a survey and document the guarding problems you observe around the mobile conveyor. Your recommendations will be part of a planned company wide guarding policy. He assigns Noah "Curly" Hair, who just recently became a mechanic's helper at this operation, to accompany you. The superintendent stresses the fact that Curly is not too familiar with safe guarding practices and asks that you take this opportunity to share your knowledge concerning guarding. You and Curly are to report back to the superintendent with your findings.

Skills developed through this classroom simulation include machine and equipment guarding strategies and procedures; hazard identification; warning and caution sign usage; safe work habits; safe guarding practices; and decisions involved in the use of factual, regulatory information in their application to specific machinery and equipment.

The exercise follows Raggs and Curly as they evaluate machine guards and discuss safe guarding practices. The efficiency of the training is noted through the opportunities to experience real-life situations and the application of factual knowledge often reserved for on-the-job learning. The classroom training and discussion provides a controlled setting for trainees to experience the consequences of both good and bad decisionmaking. The exercise itself is designed to reinforce good decisions and to correct errors when inappropriate decisions are made.

The exercise seeks to apply and reinforce important characteristics in guard design and construction. These characteristics of guard design are summarized in the widely distributed "MSHA Guide to Equipment Guarding for Metal and Nonmetal Mining" (*16*). As MSHA notes: "Such guards should:

1. Be considered a permanent part of the equipment or machine.
2. Afford maximum protection.
3. Prevent access to the danger zone.
4. Be convenient—they must not interfere with efficient operation.
5. Be designed for the specific machine, with provisions made for oiling, inspecting, adjusting, and repairing machine parts.
6. Be durable and constructed strongly enough to resist normal wear.
7. Not present a hazard in itself."

The guard might also be constructed to contain those parts that may fail or be propelled to possibly strike employees.

As participants work through the exercise, they begin to discover the difficulties that can exist in the interpretation of regulations, the necessity for safe guarding practices, and common misperceptions about guarding requirements. It is within this context that this exercise approaches training. (See the appendix for problem example.)

The exercise is now being field tested and will be revised as needed. Once completed, the exercise will be sent to the Mine Safety and Health Academy located in Beckly, WV, for distribution to those mining companies requesting machine guarding training exercises.

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SUMMARY AND CONCLUSIONS

Variability within the applied interpretations of rules, regulations, and actual work practices may be a major contributing factor in machine guarding injuries, violations, and litigation. The experimental training simulation discussed in this paper is an attempt to better define and understand differences in the interpretation and application of machine guarding regulations. The use of the 3-D slides within a realistic problem setting can improve the fidelity of safety training, thus aiding in the transfer of safety skills. The benefits of this and similar exercises could be a further reduction in the number of injuries related to improper guarding practices, less reliance on the judicial system to resolve a variety of interpretations of machine guarding regulations, and a reduced level of violations.

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APPENDIX

The appendix consists of a problem workbook and a master answer sheet. These items represent a completed exercise.

Raggs and Curly Guarding Exercise

Problem Booklet

Mining Systems and Human Engineering
U.S. Bureau of Mines
Pittsburgh, PA

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Instructions

Read the problem situation described on the next page. Then answer each of the eight questions. Do them one at a time. Some questions will ask you to look at one or more three-dimensional slides. Look at the appropriate slide or slides, then continue on with the exercise. Don't jump ahead, but look only at the questions and slides to which you are directed. However, you may look back to earlier questions and answers at any time. Follow the directions for each question.

After you have selected a choice to a question, look up its number on the answer sheet. Select your answer(s) to each question by slowly and gently rubbing the special pen between the brackets on the answer sheet. A hidden message will appear and tell you if you are right. When you have finished, you will learn how to score your performance.

The Situation

You, Earl E. Raggs, are the chief mechanic at the main mine complex of the AB Coal Co. You have been called to the Jake's Run Surface Mine. The mine supplies coal directly to rail cars by means of a 121.92-cm (48-in) mobile conveyor. The superintendent explains that during a recent insurance company inspection, some potentially dangerous situations concerning improper guarding practices were noticed. He instructs you to conduct a survey and document some of the guarding problems you observe around the mobile conveyor and make recommendations for correcting these problems. Your recommendations will be part of a planned company-wide guarding policy. He assigns Noah "Curly" Hair, who was just recently reassigned as a mechanic's helper at this operation, to accompany you. The superintendent stresses the fact that Curly is not too familiar with safe guarding practices and asks that you take this opportunity to share your knowledge concerning guarding. You and Curly are to report back to the superintendent with your findings. Turn to Question A.

Question A

You and Curly take a camera and notebook and begin to document the status of the guards located at the mobile conveyor area. Look at slide 1. You are looking for unsafe guarding practices and related problems. What should you point out to Curly? (Select as MANY as you think are correct.)

1. A dirty warning sign.

2. A missing guard.

3. Altered guard.

4. Coal spillage.

5. A missing guard around the electrical box.

When you have made your selection(s), do the next question.

Question B

Continuing your survey, you and Curly go to the rear of the bin. Look at slide 2. What hazards would you note and point out to Curly at this location? (Select as MANY as you think are correct.)

6. The salamander is located too close to the fuel depot.
7. There are holes in the guards.
8. The guard is not extended far enough to enclose all pinch points.
9. Warning signs are inadequate.
10. Coal has built up here.
11. Guard screens are not aligned.

When you have made your selection(s), do the next question.

Question C

The next place you stop is a conveyor dump point. Look at slide 3. Other than repairing the holes in the guards and cleaning up obvious spillage, what corrective measures should you recommend to the superintendent for this area? (Select as MANY as you think are correct.)

12. Replace the missing triangular guard on the near side.

13. Display warning signs.

14. Investigate the cause of the large coal chunks underneath the equipment.

When you have made your selection(s), do the next question.

Question D

You walk around the dump point to look at the other side. This is what you see. Look at slide 4. What corrective measures should you and Curly recommend to the superintendent for this area? (Select as MANY as you think are correct.)

15. Display warning signs.

16. Repair the holes in the guard.

17. Investigate the cause of the large coal chunks underneath the equipment.

When you have made your selection(s), do the next question.

Question E

You and Curly travel to the mobile conveyor. Look at slide 5. You ask Curly to assess this piece of equipment. What positive guarding practices would you expect Curly to note? (Select as MANY as you think are correct.)

18. Effective use of multiple guarding materials.
19. Extended grease fittings.
20. Handrail and toe boards.
21. Walkway is clear of all slip and trip hazards.
22. Guarding for machinery parts that are out of reach.

When you have made your selection(s), do the next question.

Question F

Curly mentions to you that he saw another example of guarding on a piece of mobile equipment. Look at slide 6. This is a refurbished piece of equipment that arrived from the factory not too long ago. After new tires are put on it, what guarding changes, if any, do you think should be made before the equipment is put into use? (Select as MANY as you think are correct.)

23. No changes should be made because this is the way it came from the factory.
24. Extend the height of the guard around the engine compartment.
25. Paint the engine compartment guards a different color than the equipment.
26. Extend the guarding down to cover the top of the tire.
27. Install warning signs and reflective materials on the step.

When you have made your selection(s), do the next question.

Question G

You decide to conclude this initial phase of the survey by asking Curly to survey his work area near where the compressed gas is stored. Look at slide 7. You see quite a few potential hazards at this site and decide to have Curly point them out to you. What should Curly point out as potential hazards? (Select as MANY as you think are correct.)

28. The handrail is lying off to the side and not attached to the steps.

29. Combustible materials are stored too close to the compressed gas.

30. There are no signs indicating compressed gas storage.

31. Batteries are not stored properly and are placed too near the compressed gas.

32. Compressed gases are not secured in place.

33. Compressed gases should be stored in metal sheds.

34. Housekeeping is poor in this area.

35. There are no fire extinguishers here.

When you have made your selection(s), do the next question.

Question H

You meet with the superintendent to brief him on your findings. Besides the condition of the guards themselves, what are some other safety practices that you might recommend to support safe work procedures around moving parts? (Select as MANY as you think are correct.)

36. Warning signs placed in close proximity to moving parts.
37. Materials used for guarding should be substantial and heavy.
38. Written procedures such as SOP's and JSA's that address specific tasks.
39. A maintenance and inspection program specifically aimed at guarding.
40. Removal of a guard only after a piece of equipment has been deenergized or locked and tagged out.
41. Guards should be designed and modified to protect maintenance personnel as well as to make their job easier.

End of Problem

Scoring your performance

1. Count the total number of responses you colored in that were marked "correct." Write this number in the first blank on the answer sheet.
2. Count the total number of incorrect responses you colored in. Subtract this number from 9. Write the difference in the second blank on the answer sheet.
3. The best score is 41. The worst score is 0.

Master Answer Sheet for the Raggs & Curly Guarding Exercise

Use this answer sheet to mark your selections. Rub the special pen gently and smoothly between the brackets. Don't scrub the pen since the message may blur. Be sure to color in the entire message once you have made a selection. Otherwise, you may not get the information you need. The last part of the message will tell you what to do next.

Question A (Select as MANY as you think are correct.)

1. [Correct. It is a good idea to clean the illegible sign. A comprehensive]
[guarding policy should include periodic cleaning of warning and]
[caution signs.]

2. [Correct. A missing guard exposes a hazard.]

3. [In many circumstances it may be necessary to alter existing guards.]
[The addition of straps to this guard strengthen and protect it.]

4. [Correct. Coal buildup can be a fire and tripping hazard. The amount]
[of coal may indicate that additional maintenance is necessary here.]

5. [The electrical box does not require additional guarding in this situation.]

Question B (Select as MANY as you think are correct.)

6. [The distance between the salamander and the fuel depot is adequate]
[and poses no hazard.]

7. [Correct. Holes in guards present a hazard because they make it]
[possible for persons to come into contact with moving parts.]

8. [Correct. Even if the guard was in good condition, the rollers would not]
[be completely enclosed by the guard. Contact with moving parts is not]
[prevented here.]

9. [Correct. Warning and/or caution signs are a good safety practice.]

10. [Correct. Coal buildup is a potential fire and tripping hazard. The]
[amount of coal seen here may indicate that equipment]
[modifications may be necessary to prevent continued spillage.]

11. [Correct. Space left between the frames of guards allows openings]
[where fingers could contact moving parts.]

Question C (Select as MANY as you think are correct.)

12. [Correct. If you look closely, you can see a triangular guard on the opposite]
[side of the structure. It may be a possible violation if a similar guard is]
[not in place on this side of the structure.]

13. [Correct. It is a good policy to include caution and warning signs as]
[part of the guarding program.]

14. [Correct. This problem needs to be addressed. Either the area should]
[be guarded so that the large pieces can be confined or the source of]
[the problem should be remedied.]

Question D (Select as MANY as you think are correct.)

15. [Correct. It is a good policy to include caution and warning signs as part of]
[the guarding program.]

16. [Correct. Holes in guards present a hazard because they make it possible for]
[persons to come into contact with moving parts.]

17. [Correct. This problem needs to be addressed.]

Question E (Select as MANY as you think are correct.)

18. [Correct. Materials used include screen, belting, and manufacturer equipped]
[guards.]

19. [Correct. Extended grease fittings and cups allow for easy greasing of]
[moving parts and are required.]

20. [Correct. Sometimes we forget that guarding includes handrails to]
[guard against the employee falling from an elevated position.]

21. [Correct. There is no problem here.]

22. [Correct. Even though they are out of reach, moving parts may break]
[and pieces may fly out and hit someone if not guarded.]

Question F (Select as MANY as you think are correct.)

23. [This is not necessarily true. Manufacturer's specifications do not always meet]
[company, State, and Federal regulatory agency guarding specifications.]

24. [Correct. The existing guard does not adequately stop access to]
[potential hazards.]

25. [Correct. This is recommended to make guards more obvious.]

26. [This is not practical. If guards were there they could restrict movement]
[of the wheels and could be a hazard.]

27. [Correct. Warning signs are good guarding practice. The use of reflective]
[materials along the catwalk of the machine and around the other guards can]
[draw attention to potentially hazardous areas, such as the step as a tripping]
[hazard.]

Question G (Select as MANY as you think are correct.)

28. [Correct. Handrails provide a means of support and guard against]
[accidental slips and falls.]

29. [Correct. Combustible materials may be an ignition source and a fire]
[could easily develop.]

30. [This is not required. The only sign required is a "NO SMOKING-NO]
[OPEN FLAMES" sign.]

31. [Correct. Batteries may be a source of hydrogen gas, which is highly]
[explosive. Batteries should be kept in a secure location to guard]
[against chemical burns.]

32. [The safety chains shown are adequate and the door is locked.]

33. [That is not a problem here. It is not recommended that compressed]
[gas be stored in metal sheds because of the potential heat buildup.]

34. [Correct. Side of stairs is broken and steps are not anchored solidly to]
[the shed. Accumulations of unmarked drums and debris create a]
[potential fire hazard.]

35. [Correct. Fire extinguishers are required because it is a wooden]
[structure that presents a fire hazard.]

Question H (Select as MANY as you think are correct.)

36. [Correct. Warning signs alert personnel to potential hazards associated]
[with moving parts.]

37. [This doesn't make a good guard. Additional hazards may be]
[introduced when trying to remove a heavy guard.]

38. [Correct. These procedures clarify safe practices to be followed]
[including guarding issues.]

39. [Correct. Through a preventive maintenance schedule and regular]
[inspection, guarding problems can be documented and corrected.]

40. [Correct. This is always a good practice. In addition, thought]
[should be given to other forces, such as belt tension and pressurized]
[liquids and gases.]

41. [Correct. One example is extended grease fittings and cups, which]
[eliminate the need to work close to moving parts when lubricating.]

End of Problem

Scoring your performance

1. Count the total number of responses you colored in that were marked "correct." Write this number in the first blank on the answer sheet.

2. Count the total number of incorrect responses you colored in. Subtract this number from 9. Write the difference in the second blank on the answer sheet.

3. The best score is 41. The worst score is 0.

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