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Professional Safety

JOURNAL OF THE
AMERICAN SOCIETY
OF SAFETY ENGINEERS

Process Safety Management

Due Diligence Considerations

■ **Ergonomics**
Investigating
a New Device
for Construction

■ **Hearing
Protection**
Effective Training
for Drillers

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contents

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features

26 Process Safety Acquisition of a PSM-Subject Facility: Considerations in Due Diligence

By David M. Einolf and Luverna K. Menghini

Due diligence in mergers and acquisitions (M&A) rarely focuses on safety and health concerns. Typically, limited site observations are combined with an assessment of workers' compensation trends. This approach ignores a significant source of potential liability—compliance with OSHA's Process Safety Management (PSM) standard. This article discusses an approach to M&A due diligence that optimizes on-site evaluation time; reduces the uncertainty associated with acquiring PSM-subject facilities; and allows an acquirer to develop a rational strategy to implementing a program consistent with the firm's PSM approach and values.

30 Ergonomics Overhead Drilling: Development & Evaluation of a New Device

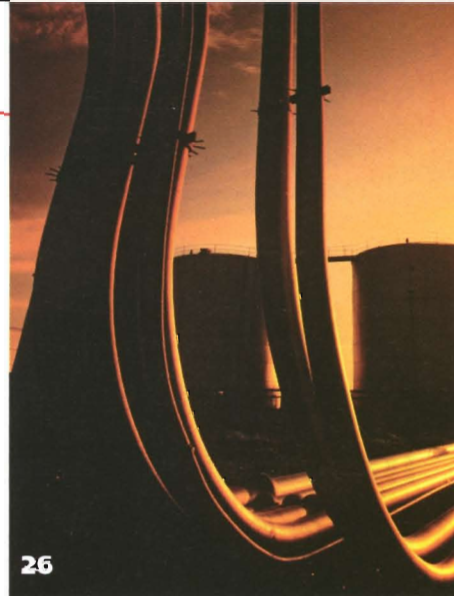
By David Rempel, Demetra Star, Billy Gibbons, Alan Barr and Ira Janowitz

Drilling overhead into concrete is a strenuous task that is associated with shoulder, arm, neck and back musculoskeletal disorders because of the forceful and awkward aspects of the task. This task is performed by construction workers in the electrical, pipe fitting, sheet metal, ironwork and carpentry trades. This article discusses a project in which alternative devices for overhead drilling were developed and field tested.

36 Hearing Protection Noise & Hearing Protection: Development of Two Training Exercises for Drillers

By Edward A. Barrett and Roberta A. Calhoun

Drillers and their helpers are among the more than 30 million American workers who are regularly subjected to excessive workplace noise. Approximately one-third of these employees eventually develop permanent hearing loss. One explanation for this problem is inadequate training. To address this issue, NIOSH developed two training exercises to inform drillers about noise, hearing loss and proper use of hearing protection. This article reviews the development and evaluation of these exercises and discusses their use and availability.



26

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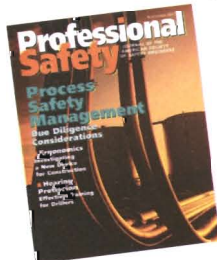
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Cover: Photo highlights this issue's lead feature, "Acquisition of a PSM-Subject Facility: Considerations in Due Diligence," which discusses an approach to mergers and acquisitions due diligence that reduces the uncertainty associated with acquiring PSM-subject facilities. Photo by James Lauritz/Photographer's Choice.

Professional Safety

JOURNAL OF THE
AMERICAN SOCIETY
OF SAFETY ENGINEERS

contents
continued

departments

6 In the Loop

7 President's Message

The SH&E profession: Pay it forward

8 Dates & Places

12 Rules & Regs

14 Industry Notes

18 Writing Worth Reading

19 Government Affairs

21 ASSE Perspectives

The Society comments on recent mining legislation.

42 Standards Developments

44 Best Practices

Strategies for managing risks from imported products.

48 Best Practices

Essential elements of a drug-free workplace program.

52 Classified Ads

56 Back Page

Thanksgiving myths and facts, photo of the month and more...



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Noise & Hearing Protection

Development of two training exercises for drillers

By Edward A. Barrett and Roberta A. Calhoun

MORE THAN 30 MILLION EMPLOYEES each year are exposed to hazardous occupational noise, and approximately one-third of them develop permanent hearing loss (NSC, 2000). Possible explanations for the latter statistic include worker regard for noise as a mere nuisance rather than as an occupational safety and health hazard, and consequent neglect of established protective measures (e.g., hearing protection); lack of knowledge concerning noise; improper use of hearing protection; worker indifference; and inadequate training (Bauer & Babich, 2004).

Many drill rigs generate high sound levels, which vary according to the type of machine, its location with respect to the physical surroundings, and the location of the sound measured around the rig. A NIOSH study measured noise output from several types of drill rigs during field investigations (Ingram & Matetic, 2003). Two types of data were recorded—the actual noise generated by the drill rig at various

duties to decrease exposure time and posting warning signs in high-noise work areas are two such controls.

Another is the use of hearing protection. Worker use of hearing protection has been disappointing, however. One study by the University of Michigan found that construction workers used earplugs and earmuffs only between 36% and 61% of the time that they were necessary (Lusk & Kerr, 1998). In a 2001 study, OSHA reported a relatively low rate of 30.4% for use of earplugs among construction workers (Walker, 2001).

Why are rates for hearing protection use so low? One explanation may be workers' lack of concern for noise in the workplace. They expect workplace noise to be a loud and inevitable nuisance and, therefore, accept it as part of the job. As a result, they disregard proven measures that can protect their hearing. Other workers may use hearing protection, but do so improperly. They may misguidedly remain in high-noise areas for extended periods thinking they are protected when in fact they are not. Other reasons for low use and/or misuse of hearing protection include poor education, lack of awareness and inadequate training (Nash, 2003).

To address the training issue, NIOSH developed two exercises from which drillers can learn about noise, hearing loss and hearing protection. The first is an invisible ink exercise, titled "Drill Rig Incident" (DRI) (Photo 2); the second is a 3-D slide reel training aid, "Wearing Hearing Protection Properly" (WHPP) (Photo 3). DRI is an instructor-



Photo 1: Impact noise: Metal on metal.

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Roberta A. Calhoun, a safety and occupational health specialist, has spent the past 19 years in the education and training branch of the Bureau of Mines and NIOSH. She holds an M.S. in Education from the University of Pittsburgh and a B.S. in Mechanical Engineering from Point Park University.

positions around the rig and the noise to which the drill operator was exposed during the drilling cycle. For the latter, sound level measurements up to 120 dBA were recorded while hammering casing (metal on metal) in drilling a water well (Photo 1).

Several types of administrative controls exist to address worker exposure to loud drill rig noise. Rotating

led training exercise for use with small groups of workers, while WHPP is a self-teaching exercise for use without an instructor.

Invisible ink exercises, sometimes supplemented with 3-D slide reels, have been used effectively for many other mining safety issues, including machine guarding, ground falls, first aid and self-rescue (Cole, Wiehagen, Vaught et al., 2001). These methods are more interactive than standard lecture or paper-and-pencil exercises, and less technology-dependent than computer-based training exercises. Feedback about the techniques is generally positive. For example, Cole, et al. (2001) reported that 60% of respondents indicated that these types of exercises are better than traditional training methods and 40% indicated the exercises were comparable. No negative responses were reported. The exercises are readily available and highly used by mining safety and health trainers (with thousands of packages distributed by NIOSH, MSHA and online at www.cdc.gov/niosh/mining/products).

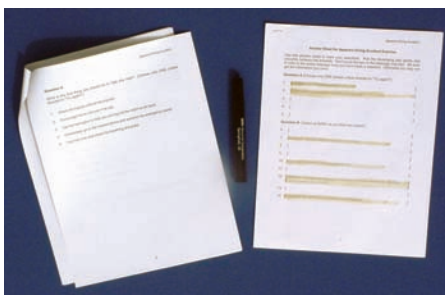
Development of Training Exercises

The initial step in developing the exercises was to identify key concepts (subject areas) to be incorporated into the training program. In selecting content material, the literature on noise and hearing protection was searched for information that would address the issues and concerns discussed earlier. First, an annotated bibliography consisting of both descriptive and conclusive reports was prepared. As articles were reviewed, relevant concepts were documented and categorized as either a) background and effects or b) driller and employer responsibilities. Background and effects included the following subject areas: sources of noise; danger of noise exposure to drillers; population at risk; safety and health effects of noise exposure; types of noise exposure; and OSHA regulations for driller exposure to noise. Driller and employer responsibilities included these subject areas: role of drillers in preventing noise-induced hearing loss; role of employers in preventing noise-induced hearing loss to drillers; warning signs; anticipation of exposure to noise at drill sites; evaluation of noise hazards at drill sites; prevention of exposure to drillers; and control of noise hazards at drill sites.

Several topics in these various subject areas were discussed with content experts and safety practitioners and the following were chosen to be incorporated into the exercises:

- basic facts about noise and hearing loss;
- indications of hearing loss;
- recognition of excessive workplace noise levels;
- dealing with loud drill rig noise;
- awareness of personal hearing loss;
- wearing hearing protection properly;
- accepting responsibility for protecting hearing on and off the worksite.

A first draft of DRI and six demo 3-D slide reels were prepared then authenticated by various industry, academia and MSHA representatives. Their



Clockwise from top left: Photo 2: Invisible ink training exercise example. Photo 3: 3-D viewer and slide reel. Photo 4: Driller looks at 3-D reel before his shift.

comments and recommendations were considered and selectively integrated into the exercises.

A pilot test study was conducted to make any necessary changes before full-scale field testing. Instructional materials and evaluation procedures (namely, pretest/posttest questions) were used in a trial run with a small number of subjects. Pilot tests were conducted with representatives from industry, MSHA, NIOSH and academia. Based on comments from participants, the exercise content was modified, particularly the use of appropriate terminology for drilling equipment, work processes and workplace conditions. After considering all recommendations and suggestions, those that were believed to improve the exercises were incorporated into the final version.

Invisible Ink Exercise

The invisible ink exercise begins with background information about a drilling crew and a job they are trying to complete. This is followed by the description of a problem scenario for the drill crew foreman. The trainee assumes the role of the foreman and sets out to handle the problem. After reading the background information provided, the trainee proceeds to answer a series of 11 questions (A through K) in sequence. Each question has at least one correct answer and some have multiple correct answers.

After reading a question and selecting an answer, the trainee turns to the answer sheet that contains

Abstract: Drillers and their helpers are among the more than 30 million American workers who are regularly subjected to excessive workplace noise. Approximately one-third of these employees eventually develop permanent hearing loss. One explanation for this problem is inadequate training. To address this issue, NIOSH developed two training exercises to inform drillers about noise, hearing loss and proper use of hearing protection. This article reviews the development and evaluation of these exercises and discusses their use and availability.

sets of empty brackets corresponding to answer choices. The trainee then uses a special developing ink pen between the appropriate brackets to reveal feedback information that was printed using invisible ink. From the feedback, the trainee learns whether the answer is correct or not, and why. The feedback also provides valuable additional information from which trainees can learn more about concepts being taught in the exercise.

3-D Slide Reel Training Aid

The 3-D slide reel training aid contains colorful visuals with embedded words in each stereo scene. The scenes realistically illustrate the proper use of two types of hearing protection—foam earplugs and earmuffs. As part of their training, workers are asked to look at the 3-D reel as a reminder of how each type of protection should be properly worn. This may be done anywhere, even in a pickup truck at the drill site before starting a workday (Photo 4, p. 37).

Examples from DRI & WHPP

DRI: Question G

The sidebar (“DRI Example”) shows an example from DRI. The six questions leading up to this question in the DRI scenario relate to the following incident involving a driller helper: “Eager to pre-

vent a similar incident from occurring to other workers, the company safety manager, Rip, decides to develop a training program to teach workers about noise and hearing protection.” As part of this company training program, Question G points out that workers should be capable of determining for themselves whether they have a hearing loss by paying attention to various cues. Question G is followed by a series of six answers, five of which are correct. The answers within the brackets are the actual words that are printed using invisible ink. Instructor discussion notes follow the answers. The discussion notes serve two purposes—to provide additional subject information for use by a trainer, if desired, and to explain the rationale for some of the answer choices.

WHPP: Scene 2

In the 3-D slide reel training aid example shown in the “WHPP Example” sidebar, a driller “rolling and squeezing a foam earplug” is shown. The discussion notes are intended to provide additional helpful information about preparing foam earplugs for insertion.

Evaluation of Training Exercises

To determine the effectiveness of DRI for meeting its instructional objectives, a split-group pretest/posttest experiment and an eight-item Likert scale self-reporting measure were administered to 180 participants. The study group consisted of persons who have varying levels of actual hands-on drilling experience. The experimental design has strong internal validity, as persons were randomly selected to take either a pretest or, following training, a posttest, but not both. Those who took the posttest scored significantly higher ($p < .01$), and it was concluded that the improved score was a result of the training.

The self-reporting measure was used to determine the validity and utility of the exercise. More than 73% of the participants indicated that they “learned something new from the exercise” and nearly 90% said that they “will use some of the ideas presented to protect their hearing.” The utility of the exercise was also high, as approximately 90% of the participants reported that “the way the material was presented is a good way for me to learn.”

To determine the effectiveness of WHPP, 101 participants were given an eight-question, multiple-choice pretest and posttest immediately before and after viewing the 3-D slide reel. This study group also included persons who have a broad range of hands-on drilling experience. Again, participants scored significantly higher on the posttest ($p < .01$), and it was concluded that the objectives of the instruction were achieved.

DRI Example

Question G

You think that the program should teach workers how to recognize signs of hearing loss. You want to suggest ways that they can judge for themselves if their hearing is bad. Which of the following would you recommend that Rip include in the training? (Select as MANY as you think are correct)

- 30. They often ask people to repeat what they are saying.
- 31. Someone tells them they talk too loud.
- 32. They have trouble hearing normal conversation.
- 33. They complain about people mumbling.
- 34. They have constant ringing or buzzing in their ears.
- 35. Others complain that the TV is too loud.

- 30. [Correct. If this happens most of the time, it's one sign that a person may]
[have a hearing loss.]
- 31. [This doesn't necessarily mean they have a hearing problem. A loud]
[voice may be normal for some people. Try again.]
- 32. [Correct. In most cases, this points to a hearing loss.]
- 33. [Correct. With a hearing loss, it is difficult to hear all of the sounds that]
[are spoken. Talk may sound like people are mumbling.]
- 34. [Correct. Called tinnitus, this is a classic symptom of hearing loss.]
- 35. [Correct.]

Discussion (from the instructor's discussion notes)

The correct answers are 30, 32, 33, 34 and 35. It's important for workers to be able to assess their own individual level of hearing. They are more likely to protect the hearing they have left when they know and accept the fact that some of their hearing is gone. Workers need to be aware that one sign of a hearing loss is asking others to repeat what has been said (30). Problems hearing normal conversation (32), complaints about people mumbling (33) and having to turn up the volume on the TV (35) are also signs of hearing loss. Constant buzzing or ringing in the ears, called tinnitus (34), can also indicate a hearing loss.

WHPP Example

Scene 2

Before inserting foam earplugs, they should be rolled into a thin crease-free cylinder. To get the diameter of the cylinder as small as possible and crease-free, begin by squeezing the earplug lightly as it is being rolled between your forefinger and thumb. Then gradually apply progressively greater pressure as the plug becomes more tightly compressed.

The earplug may also be rolled in a person's palms to achieve the thin, crease-free cylinder. This may be necessary for the person who has small or thin fingers, in which case the cylinder could end up in a distorted "barbell" shape.

A mistake that some workers make is to unintentionally roll the foam earplug into a ball or cone, instead of a cylinder. This results in a configuration that cannot be inserted very far into the ear canal and, therefore, cannot provide effective protection.



Drill Rig Incident

DRI was evaluated to determine its effectiveness for teaching workers about noise, hearing loss and hearing protection. A sample of 180 people participated in a field experiment that consisted of two parts. In the first part, participants completed either a pretest before working the exercise or a posttest after working it. The experimental procedure used in the first part may be described as a "split-group" pretest/posttest assessment. This means that each of the 180 participants in the sample group was placed by random draw into either a pretest or a posttest group. Those in the pretest group took the test before working the DRI training exercise, and those in the posttest group took the test after working DRI. The dependent variable in the experiment was participants' scores on either the

pretest or posttest. No one in this sample completed both the pretest and posttest.

The rationale for dividing the sample was to ensure that those completing the posttest would not be sensitized to the questions by first taking the pretest, which might have, thereby, led to incorrect inferences. The second part of the experiment consisted of all subjects answering questions (called a self-reporting measure) relating to their opinion on the validity and utility of the exercise.

The pretest and posttest each contained 24 identical true-or-false questions about the topics included in DRI (namely noise, hearing loss and hearing protection). The assumption was that if the posttest group's average test score was higher than that of the pretest group, the posttest group likely gained some knowledge about noise, hearing loss and hearing protection as a result of working the DRI exercise. If this was the case, it is believed that DRI is one reason for the information gain and, therefore, is an effective training exercise.

In this type of investigation, it is important that the test groups are equivalent. For research purposes, this means that subjects have comparable backgrounds and work experience, as well as similar levels of training material content knowledge coming into the experiment. If the groups are credibly equivalent, it can be argued that improved scores in the posttest are linked largely to the DRI training received and minimally to any outside effects.

Table 1

Demographics of Subjects

	Pretest group			Posttest group		
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>
Age	103	42.0	11.6	71	43.5	10.1
Years' experience	96	13.3	12.1	96	13.3	10.0

Table 2

Independent Samples *t* test

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i> -value	<i>p</i> -value
Pretest group	108	18.87	2.24	4.11	< .0001
Posttest group	72	20.22	2.04		

Table 3**Self-Reporting Results**

Statement	<i>n</i>	Agree % ^a	Disagree % ^b
1) This situation could happen at a drill site.	179	92.2	0.6
2) The exercise will help me remember something important about noise and hearing loss.	179	88.2	1.1
3) I learned something new from this exercise.	179	73.3	6.2
4) The exercise took too long to complete.	179	4.5	76.5
5) I liked working the exercise.	179	66.5	8.4
6) I will use some of the ideas presented to protect my hearing.	179	89.4	1.1
7) The way the material was presented is a good way for me to learn.	179	89.9	2.8
8) The exercise was easy to read.	179	91.6	1.7

Note. ^aAgree percentage is determined by adding together the number of 4 and 5 responses and dividing by *n*. ^bDisagree percentage is determined by adding together the number 1 and 2 responses and dividing by *n*.

The total agree and disagree percents in the table add up to less than 100% because the percent of 3 responses is not shown. In other words, 100% - (agree % + disagree %) = percent of 3 responses.

With a sufficiently large sample of participants (a minimum of 10 to 15 per group is a good rule of thumb), randomly assigning members can produce virtually equivalent groups in all respects. The authors claim that both groups in this experiment are credibly equivalent because 1) their demographics (Table 1, p. 39) indicate equivalency in terms of age and drilling experience; 2) the groups are statistically large enough; and 3) subjects were randomly placed into either group.

Both the pretest and posttest scales consisted of 24 true/false items. Scores on each test had a possible range from 0 to 24 correct. Results in an independent sample *t* test (Table 2, p. 39) showed that the mean posttest score (20.22) was significantly higher than the mean pretest score (18.87). With reference to the experimental design discussed earlier, this significant difference in scores suggests that trainees learned something about noise, hearing loss and hearing protection from participating in the DRI exercise. Thus, it can be concluded that the training exercise is instructionally effective, at least to some degree.

The second part of the experiment consisted of participants indicating their level of agreement (on a scale from 1, definitely disagree, to 5, definitely agree) with eight statements. This self-reporting measure was used to assess the validity and utility of DRI as a training exercise.

Statements 1, 2 and 3 report on participants' assessment of the validity of DRI. As shown in Table 3, 92.2% indicate that the "situation could happen at

Table 4**Paired *t* test**

	<i>M</i>	<i>SD</i>	<i>t</i> -value	<i>p</i> -value
Pretest	6.13	0.998		
Posttest	7.24	0.978	9.38	< .001

Note. *n* = 76.

a drill site"; 88.2% agree that DRI will help them "remember something important about noise and hearing loss"; 73.3% indicated they "learned something new" from DRI. Finally, 89.4% of the participants indicate they will "use some of the ideas presented to protect" their hearing. The utility of the exercise was high as well, as almost 90% of the subjects reported "the way the material was presented is a good way for me to learn."

Wearing Hearing Protection Properly

The 3-D slide reel training aid was evaluated to determine whether it is effective for teaching drillers about the proper use of foam earplugs and earmuffs. A simple field experiment was conducted using a sample of 76 individuals. The participants were volunteers recruited from conference workshops (sponsored by the National Drilling Association and the National Ground Water Association) and drilling company training classes.

The following experimental procedure was used: Participants were asked to answer eight multiple-choice questions related to using both types of hearing protection. They were then told to take as much

time as needed to view and understand the information shown in all seven scenes on the 3-D slide reel. Next, they were instructed to review their answers in the multiple-choice test and change any they believed to be incorrect. To facilitate this, two sets of answer choices were placed on the multiple-choice test sheet, one set in blue (answered before the training) and the other set in red (answered after the training). It was hypothesized that their decision to change answers would be directly related to what they learned from the 3-D slide reel training aid.

The number of correct answers recorded after viewing the 3-D reel (posttest) was expected to be greater than the number of correct answers recorded prior to viewing the reel (pretest). Such an outcome would support the belief that subjects would learn about the proper use of hearing protection from WHPP. It could then be concluded that the 3-D slide reel is an effective training aid.

As shown in Table 4, subjects had more correct multiple-choice answers after viewing the 3-D slide reel (7.24) than before (6.13) and the changed score (Δ) was highly significantly different from zero. It was concluded, therefore, that the 3-D slide training aid was an effective method for teaching drillers about wearing hearing protection properly.

Conclusion

Both training exercises were shown in field experiments to be effective for teaching workers in the drilling industry about noise and hearing protection. As demonstrated by the field data presented, these two training exercises are effective for teaching drillers and others who work at drill sites about the hazards of noise and the benefits of wearing hearing protection. Similar exercises developed effectively can help address some of the barriers to hearing conservation—worker disregard for noise as an occupational safety and health hazard; neglecting to wear or improperly wearing hearing protection; lack of knowledge concerning noise; and inadequate training. With similar training exercises developed for other occupational settings, hearing loss due to excessive workplace noise can be prevented. ■

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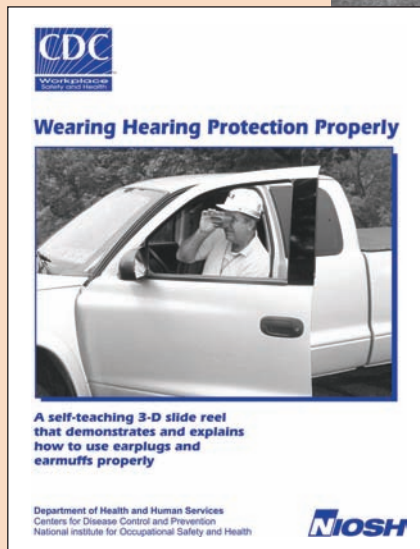
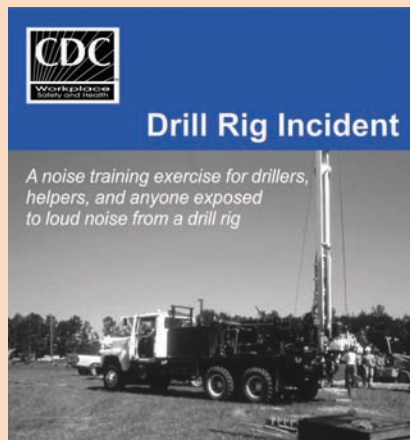
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Availability of Training Exercises

"Drill Rig Incident" and "Wearing Hearing Protection Properly" each is available as an instructor's copy, a practical format that includes additional information to help trainers or safety personnel implement the exercises.

The DRI instructor's copy contains most of the materials trainers will need to use the exercise. It includes suggestions for using the exercise, performance objectives for the training, master answer sheets, a scoring key, discussion notes that provide additional subject information and a summary of field test results in which the effectiveness of DRI was determined. The instructor's copy also includes four appendices: Appendix A is the complete exercise problem booklet, which may be reproduced. Appendix B contains answer sheet blanks. These are furnished for employers who wish to have the invisible ink answers (which appear in Appendix C) printed at their location or by a local printer. Answer sheets are consumable; one is needed for each group of three to five participants who work the exercise together. Alternatively, an individual trainee may have his/her own answer sheet. Appendix D contains the 24-question pretest/posttest that was used in the field evaluation of DRI.

The WHPP instructor's copy contains similar information needed to use the 3-D slide reel for training. It offers practical suggestions on how to use the reel as a training aid, performance objectives, discussion notes that provide additional information to the user and a summary of field test results in which the effectiveness of WHPP was determined. The publication includes one appendix—an eight-question pretest/posttest that was used in the field evaluation.



"Drill Rig Incident" [DHHS (NIOSH) Publication No. 2005-108] and "Wearing Hearing Protection Properly" [DHHS (NIOSH) Publication No. 2005-107] are available, without charge, by contacting Bobbie Calhoun, NIOSH Pittsburgh Research Laboratory, 626 Cochran Mill Rd., P.O. Box 18070, Pittsburgh, PA 15236; (412) 386-5901; fax (412) 386-5902; minetraining@cdc.gov.