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Mine Safety Education and Training Seminar

Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, May 17, 1988; Beckley, WV, May 19, 1988; St. Louis, MO, May 24, 1988; and Reno, NV, May 26, 1988

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UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
T S Ary, Director

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PREFACE

In May, 1988, the Bureau of Mines held technology transfer seminars on mine safety education and training at Pittsburgh, PA, Beckley, WV, St.Louis, MO, and Reno, NV. The papers presented at those seminars are contained in this Information Circular, which serves as a proceedings volume. The papers highlight the Bureau's most recent research aimed at improving the effectiveness of mine safety training in order to reduce workplace accidents. Areas addressed by this research and published in this volume include training strategies for SCSR donning, a work crew performance model, hazard recognition, human factors contributions to accidents, a blasters training manual, simulated mine emergency problems, and first aid role play simulations.

The technology transfer seminar used as a forum for the transfer of this research is one of the many mechanisms used by the Bureau of Mines in its efforts to move research developments, technology, and information resulting from its programs into industrial practice and use. To learn more about the Bureau's technology transfer program and how it can be useful to you, please write or telephone:

Bureau of Mines
Office of Technology Transfer
2401 E Street, NW.
Washington, DC 20241
202-634-1224

CONTENTS

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	pct	percent
h	hour	s	second
in	inch	st	short ton
min	minute	yr	year

MINE SAFETY EDUCATION AND TRAINING SEMINAR

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ABSTRACT

Education and training research is a major component of the Bureau of Mines human factors research program. The goal of human factors research is to enhance human performance for the purpose of improving both safety and the profitability of the minerals industries. This is achieved through the design of mining equipment, work tasks, management procedures, and development of human resources. This proceedings volume presents several new developments that are helping to improve the quality and efficiency of health, safety, and occupational skills training in the mining community. Several papers address the issue of how to teach and assess miner abilities to deal with underground mine emergencies. Other papers examine practical procedures for defining and cost-justifying the integration of structured training and other performance improvement strategies to enhance the proficiency of the work system.

EFFECT OF TRAINING STRATEGY ON SELF-CONTAINED SELF-RESCUER DONNING PERFORMANCE

By C. Vaught,[1] M. J. Brnich,[2] and H. J. Kellner[3]

ABSTRACT

The purpose of this Bureau of Mines study was to assess the impact of three different instructional strategies upon trainee ability to don self-contained self-rescuers. The strategies, designed to deliver the same introductory content, were a live demonstration, a structured lecture, and a computer-based format. One hundred fifty-five subjects were randomly assigned to groups that had their initial donning instruction conveyed by one of the three strategies. The trainees performances were then assessed using a number of different measures. It was found that delivery strategy had a modest initial influence upon how well people did, but that this effect tended to disappear after one initial hands-on experience. It was also noted that a significant amount of skill degradation occurred during the first 3 months following training.

INTRODUCTION

Since 1940, there have been over 18 major explosions and more than 1,000 fires in underground coal mines in the United States (McDonald and Baker (1),[4] and Richmond, Price, Sapko, and Kawenski (2)). In a majority of these incidents, loss of life and property were minimized by the exercise of good judgment and the effective use of mining skills on the part of workers in the situation (McDonald and Baker (1)). This conclusion is in agreement with much of the recent literature dealing with human actions in emergencies, which suggests that people do not necessarily panic and become incapable of taking effective action (Sime (3)). Rather, they engage in adaptive behavior based on choices made from among those perceived to be available at any particular time during the emergency. The variable factor is how well a person uses all available information to arrive at a choice. That is one of the elements of judgment and decision making. Once a decision is made to implement a specific corrective, the variable factor may become one's ability to carry out that course of action successfully. The problem of whether an individual has the necessary procedural skills involves the area of task competency. A case in point is provided by a series of recent studies undertaken by the University of Kentucky and the Bureau of Mines.

[1]Research sociologist, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.
[2]Mining engineer, Product Research Incorporated, Pittsburgh, PA.
[3]Industrial engineering technician, Pittsburgh Research Center.

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

BACKGROUND

In open-ended interviews with more than 50 mine safety experts, Cole (4) recorded several accounts of worker failure to use self-contained self-rescuers (SCSR's) to escape toxic mine atmospheres. The prevailing assumption among those respondents offering such accounts appeared to be that workers are generally proficient in donning SCSR's. All new miners are given training, which includes a demonstration of the respiratory devices used at their mine. In addition, each 8 h annual refresher class includes a course on the use, care, and maintenance of self-rescue and respiratory apparatus. In the absence of empirical evidence to the contrary, that instruction has been accepted as being sufficient. Reputed failures of workers to don the devices in situations calling for their use were most often attributed to poor judgment, panic, or both. Other evidence from the investigations, however, has cast doubt on the adequacy of current SCSR task training and suggests that lack of procedural skills may be an important consideration.

The researchers conducted an extensive review of existing training materials and found logical inconsistencies that suggest that a task analysis might not have been done prior to training material development. Task analysis would begin with the function of the apparatus—to enable a miner to isolate his or her lungs from the ambient air—and determine empirically the most effective sequence of actions for getting the SCSR into operation. The following problems, which are discussed in detail elsewhere (Vaught and Cole (5)), run counter to that protocol: First, the recommended donning position is difficult under most mining conditions, and impossible for miners working in low coal. Second, the donning sequence appears inefficient, placing nonessential and time-consuming tasks such as strap adjustment ahead of some of the steps necessary to isolate one's lungs from the ambient atmosphere. Third, the materials do not present a simplified, easy-to-remember set of procedural rules to help miners order the complex array of tasks needed to get the apparatus on in an emergency.

In the opinion of the investigators, those logical problems with instructional content were not the only indicators that generally available SCSR task training may be insufficient. Summary statistics from 15 mine trainer workshops supported the widely held notion that a majority of underground miners never have hands-on experience with the apparatus (Cole and Vaught (6)). This was a cause for concern in view of the evidence suggesting that infrequently used procedural skills must be overlearned if proficiency is to be maintained, and that the overlearning of procedures having a motor component requires hands-on training (Johnson (7) and Hagman and Rose (8)). Given the critical nature of SCSR donning as a corrective action, the industry tendency to rely upon films, slide-tape programs, or demonstrations by an instructor instead of upon performance trials by the trainees seemed less than optimal.

As part of their effort to show what an optimized SCSR training program might include, the researchers conducted a detailed task analysis using a controlled experiment in which 36 working miners who had recently gotten refresher training were videotaped in performance trials with the SCSR model in use at their mine. Assessment of the tapes allowed the investigators to target those steps in the procedure where most errors occurred and where most time was lost. It was found that individuals spent a majority of their time adjusting straps and locating goggles that had been dropped on the floor. In addition, many of the subjects became confused and omitted tasks such as putting on the nose clips. Only 22 individuals (61 pct) were able to complete the minimum of steps necessary to isolate their lungs, and approximately half of these required over a minute to do so.

RESEARCH PROBLEM

Based on the experimental findings, an instructors manual and short videotape demonstration were prepared for field testing. This package presents a generic procedure for the four SCSR's in common use (CSE, Draeger, MSA, and Ocenco). It offers the following: (1) a donning position (kneeling) that is easy and efficient, (2) a donning sequence that moves critical steps (those tasks necessary to isolate one's lungs) ahead of the others, and (3) a set of "chunked" procedural rules that facilitate easy retention. The present study focuses upon two aspects of the effectiveness of training strategies used to deliver this new donning method. First, the effect of "front-end" complexity and feedback capability was investigated using three different treatments. Each of these treatments required differing levels of involvement on the part of the subjects. The second part of the study deals with the impact of the three treatment strategies upon trainee ability to retain and demonstrate procedural skills 90 days after initial training. It was expected that the type of involvement required to learn the procedure would affect the subject's proficiency with the motor tasks during initial performance trials, as well as his or her capacity to remember and do the procedure at a later date.

METHOD

During a 2-week period in July 1986, professional and technical employees at the Bureau's Pittsburgh Research Center, many of whom make regular visits to mine sites, were given 8 h of annual refresher training for underground miners. This training was performed according to a plan filed with the Mine Safety and Health Administration (MSHA), pursuant to title 30 Code of Federal Regulations, part 48. The classes were conducted by two MSHA approved instructors, and the curriculum conformed generally with that required of the industry. As part of the course of instruction, the students received task training in the new method of donning an SCSR.

TASK CONTENT

The actual training scheme involved having each subject put on a Draeger OXY-SR 60B as if he or she were trying to escape a fire or explosion. There are 19 discrete steps in this activity, and as might be inferred, it comprises a number of possible procedural sequences with an extensive motor component. Although there are necessary conditions for beginning certain steps, each step in any possible sequence is relatively simple from the standpoint that it does not have to mesh with other steps in order to be completed. The task itself is potentially confusing, however, because there are several sequences in which the complete procedure could be done. Nevertheless, as was stated earlier, there is a sequence which is most logical. For the present research the task was made exacting by the fact that it had to be performed without prompting, in the sequence that prior analysis had determined to be most efficient, and within a specific timeframe.

The new 3+3 (three critical and three secondary actions) donning method taught to the trainees contains a chunked sequence of actions that imposes a uniform structure upon the variable discrete steps that combined make up a particular action (depending upon the SCSR model being donned). For example, to fully activate oxygen on the Draeger one is required to (1) lift the opening lever, (2) remove the metal closing clamp, (3) grasp the lid and pull until the split pin is out of the chlorate starter, (4) insert the mouthpiece, and (5) exhale into the breathing bag to activate the bed of potassium superoxide. To fully activate oxygen on the Ocenco, a person would (1) pull the latch rod, (2) release the latches, (3) open the case, (4) open the oxygen valve, (5) inserting the mouthpiece and (6) inhale deeply to open the demand valve and fill the breathing bag. The structure that the generic method imposes upon the donning task not only presents the chunked actions in a logical sequence, but also constrains the discrete tasks to be performed in a consistent order.

INSTRUCTIONAL CONTENT

The core of information delivered to trainees learning the new method provides a two-stage approach to the donning task. First, it presents an efficient position and orientation of apparatus designed to make the chunked sequence possible. Directions for the first stage are as follows: (1) *Kneel.*—place the SCSR on the floor in front of you— lay your miner's cap on the floor and shine the lamp on the SCSR—work with both hands; and (2) *Loop.*—quickly loop the neckstrap over your head in order to position it and the case—leave the strap loose so you will have room to work—now you are ready to begin the 3+3 donning procedure. Directions for the second stage divide the chunked sequence into the three critical actions necessary to isolate one's lungs, and the three secondary actions needed to prepare an individual to escape: (1) activate the oxygen, (2) insert the mouthpiece, (3) put on the noseclips, (4) then put on the goggles, (5) adjust straps, and (6) replace miner's cap. The strategies for transmitting this message were varied for purposes of the present study, but the content remained the same.

CHARACTERISTICS OF THE THREE INSTRUCTIONAL STRATEGIES

Treatment A was a computer-based training program that presented the 3+3 method as sequential blocks of information, each block followed by a series of questions designed to determine whether the individual had learned and retained the material. Wrong answers were remediated by looping the respondent back through the block from which the question was taken. At the end, a short review exercise reiterated the critical and secondary donning actions. This approach required the most active involvement in terms of verbal learning, not only because of the amount of interaction necessary to obtain the front-end information, but also because the subjects were not cued by either the actual apparatus or the paper-and-pencil configuration. In order to reinforce what had been learned, instruction was followed by a videotape demonstration of a trainer putting on an SCSR as if he were in an actual emergency.

Treatment B was a structured lecture that utilized an advance organizer. Using overhead transparencies, the instructor presented the two stages of the new method and discussed the rationale behind each chunked action. Students were next familiarized with an evaluation form that utilized a connect-the-dots configuration and was designed to help individuals reproduce the procedure on paper. Trainees were then given copies of the form and prepared to watch videotaped demonstrations of two trainers donning the apparatus in real time. Active participation was required in that the students were asked to evaluate the first performance by drawing a line to each dot in succession as the trainer completed the action that particular dot represented. In a sense, this activity competed with the visual stimuli, although it had the desired goal of involving the students. At the conclusion of the first demonstration the tape was stopped and feedback given by the instructor, who accompanied his discussion with an overhead transparency depicting an accurately completed evaluation form. The trainees were offered another opportunity to practice the sequence by following the actions in the second performance. Feedback was again provided. The instructor closed the lecture with an overhead transparency representing a hypothetical evaluation of a poor donning trial, and stressed the consequences of doing the critical actions incorrectly.

One of the simplest ways to introduce a procedural task is to have a competent person demonstrate the routine. Indeed, much SCSR instruction, especially in the context of hazard training, consists of just that. Accordingly, treatment C involved having the trainer who had helped perfect the 3+3 method talk groups of subjects through the task, step-by-step, as he slowly donned the apparatus. This live demonstration was followed by a videotape performance of the same individual putting on an SCSR as if he were preparing to escape a mine fire or explosion. The purpose of the videotape was to give the trainees a sense of how a proficient donning execution appeared in real time. As is evident, this approach offered nothing but the basics. First, it did not require the active participation of the trainee in obtaining the front-end knowledge necessary to carry out the procedural task. Second, it did not provide any type of advance organizer to help cue the person's memory when it came time for his or her performance trial. Third, there was no feedback in terms of reiteration of correct steps, or additional information about the consequences of doing a step incorrectly.

PERFORMANCE CRITERION

Ultimately, the act of donning an SCSR is a motor task. Therefore, it was determined that the subjects must demonstrate proficiency by donning the apparatus. In the real world, whether or not one would be considered competent might actually be decided by whether one could use the SCSR to escape a toxic mine atmosphere. The experimental corollary to this practical criterion would probably entail checking to see if an individual could isolate his or her lungs and secure the SCSR adequately within an acceptable length of time, regardless of the sequence of discrete steps. There were two problems with using this sort of indicator in the present study. First, an important part of the research focuses upon skill retention. It would be very difficult to suggest forgetting as a cause of sequencing change or errors if it could not be shown that the subject had at least one systematic and error-free performance. Second, and just as important, it is known that large skill decrements exist with seldom-used procedural tasks (Hagman and Rose (8)). It seemed advisable, within the constraints of the training situation, to allow as much learning to take place as possible. The proficiency level established for the annual refresher trainees was a perfect sequence to be completed in 90 s or less, with the critical part of the sequence to take no more than 45 s. The first trial in which the subject recorded a perfect sequence within the acceptable time was designated the criterion. It was against this criterion that all subsequent performance would be measured.

EXPERIMENTAL PROTOCOL

One hundred fifty-five subjects are included in the ongoing training experiment of which this study is a part. None had extensive prior experience with any type of self-contained breathing apparatus and had never received hands-on SCSR training. In this respect, at least, they were considered to be somewhat like working coal miners; there was no preexisting procedural knowledge that might influence their performance.

At the beginning of each training class individuals were given serial numbers that were to be used to identify them for various purposes throughout the course of the research. The first use of the serial numbers was to enable the trainers to draw lots for random assignment of subjects to groups that would have their initial donning instruction conveyed by different delivery strategies. Following instruction on general hazards, mine maps and escapeways, checkin and checkout procedures, and personal protective equipment, class members were randomly divided into two groups and sent to separate classrooms. There, they were rotated through three assignments: a first aid simulation using either computer-based training or a paper-and-pencil format; roof and rib hazard identification utilizing stereoscopic viewers and three-dimensional slides; and one of the three instructional treatments for SCSR donning. Each classroom was the site of a different delivery strategy.

An alternating protocol had been designed that would enable the trainers to present any two of the three treatments to each training class. The treatments being given on a particular day depended upon the rotation plan in effect. For instance, plan A, which was implemented on the first day, specified that the structured lecture would be used in one room and the computer-based training presentation would be used in the other. Plan B, in effect on the second day of classes, offered the computer-based training and the live demonstration. Plan C, the strategy for the third day, made provision for the live demonstration and the structured lecture. On the fourth day the rotation was repeated.

Immediately following instruction the subjects were taken, one at a time, to an isolated room for a donning trial.

This performance was to serve three purposes. First, an analysis of initial attempts would permit an evaluation of the effectiveness of the strategy used to deliver the front-end donning instruction. Second, the donning trial would provide the motor component, which was considered to be crucial for proficiency at the procedural task. Third, by requiring each person to perform to criterion, the researchers were establishing a baseline from which to assess the magnitude of forgetting over time.

Prior to the performance trial, each individual was equipped with a miner's belt, cap, and caplamp. An SCSR, with its neck strap adjusted all the way out, was placed on the floor approximately four case lengths in front of the subject. The trainee was requested to await a signal from the trainer, and at this signal to put the SCSR on as if he or she were in an actual mine emergency. No questions were answered or information given at this stage of the process. During the donning trial, which was performed with no prompts, the trainer evaluated the subject's proficiency by means of a specially designed connect-the-dots evaluation form intended to show sequencing errors and actions that were done incorrectly (fig. 1). A helper recorded times for both the critical actions and the secondary actions. At the end of the trial, if an error had been made, the instructor pointed it out and explained how to do that particular step correctly. The apparatus was repacked and the student was asked to try again. This procedure was repeated until each individual reached the criterion of a perfect sequence within the specified times.

At the conclusion of the 1986 annual refresher training period, individuals' serial numbers were again randomly drawn (by treatment) to designate subjects who would get followup training and a 90-day retention evaluation. The training, given to half the subjects in each treatment group who had been selected for the 90-day recall, consisted of a quick and simple refresher. The refresher was administered 30 days before the recipient was to have his or her 90-day evaluation. People who had originally received the computer-based format were brought to a training room where they worked through an abbreviated version of their original. instruction. Individuals who had gone through the structured lecture were visited in their workplaces by a trainer who gave each person a copy of the evaluation form and asked him or her to reproduce the procedure on paper. After the subject had connected the dots to indicate the order of actions he or she believed to be the correct sequence to follow, the trainer pointed out any sequencing errors and reiterated the correct procedure. For those who had originally gotten the talk-through and live demonstration, the refresher entailed having a trainer visit each person's workplace and do the live demonstration once again.

Seventy-two subjects were chosen to participate in the 90-day retention evaluation. There were 24 individuals for each of the three treatment conditions: 12 who had been refreshed and 12 who had not. Each person in the sample was scheduled to be recalled on or about the 90th day following the date on which he or she had been initially trained. At the determined time, the subject was taken to a laboratory room which contained a videocamera. The purpose of the study was explained briefly, and a one-page interview schedule was administered by a researcher (fig. 2). Following completion of the interview, the subject was outfitted with a miner's belt, cap, and caplamp. An SCSR, with its neck strap adjusted all the way out, was placed on the floor approximately four case lengths in front of the trainee. The individual was instructed to await a signal from the trainer, and then to put the SCSR on as if he or she were in a mine fire or explosion. During the performance trial, which was done with no prompts, one trainer evaluated the process while another trainer recorded critical and secondary times and videotaped the activity. Following the donning trial, the subject reviewed the evaluation form and then watched his or her videotaped performance. A trainer pointed out any errors and suggested ways to correct them. The trial was not repeated.

PROFICIENCY MEASURES

There were three means of evaluating the performance trials. Taken together, they provide a good assessment of the effectiveness of those training strategies used to deliver the initial donning instruction. First, it was possible to record both the number and types of errors committed. This includes sequencing errors, omissions, and incorrect execution of particular steps. Second, there were two measures of time: the number of seconds a subject required to isolate his or her lungs, and the amount of time he or she took to complete the entire procedural task. Third, the number of trials necessary for each individual to reach criterion were recorded. For purposes of this study, data on these variables were obtained for the initial donning trials and the 90-day evaluation. Data management techniques are discussed in the following section.

DATA MANAGEMENT

During the initial phase of the SCSR donning study, 262 records were obtained for the 155 subjects included in the ongoing training experiment. The reason there are more data records than subjects is that some trainees required more than one trial to reach criterion. In addition to these initial records, the project staff planned to collect further information on the performance of the trainees at predetermined dates during the course of the experiment. For this reason the person- oriented information system for educators (POISE) data management software was chosen. POISE permits ready expansion so that additional data may be added, and is flexible enough to allow easy interfacing with a statistical package for the social sciences (SPSSx), the statistical package selected for use in the analysis. Three files are needed to make use of the POISE data management system: a description file, a data file, and a screen format file. For the present experiment, however, it

Performance Evaluation for ________________________ Date ____________

1. Did the miner answer the following?

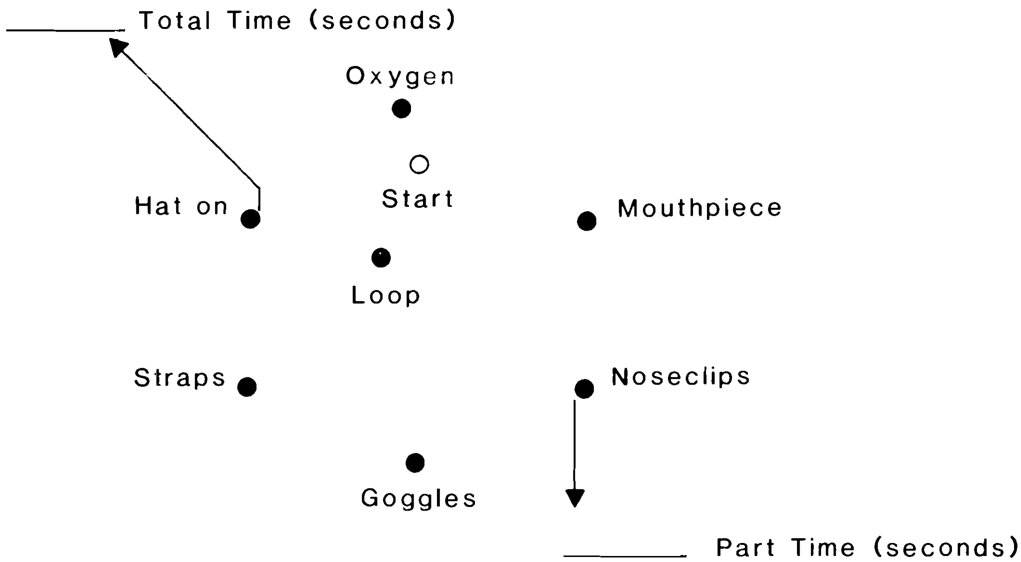
   A. Name the exact place where you started working last shift.

   _______Yes _______No

   B. Tell me how to get to the nearest SCSRs from that place.

   _______Yes _______No

2. Connect the dots in the diagram below to show the steps the miner took in donning the SCSR. DO NOT TOUCH THE DOT IF HE OR SHE DID THE STEP INCORRECTLY.



3. After the task is completed please list any errors that need to be corrected and then correct them.

Trainer's Signature ________________________

FIGURE 1.—Evaluation form for use in teaching and assessing the 3 + 3 donning method.

Interviewer ____________ Date ____________ Time ____________

Subject Name ____________ Serial No. ____________

Treatment ____________ Refresher (if yes, date from records) ____________

1. Person's Age ________ 2. Gender ________ 3. Education (yr) ________

4. Person's Job Classification ____________

5. How many times have you put an SCSR on.......

   a. Like this model? ____________

   b. Another model? ____________ (specify all) ____________

6. Explain the circumstances under which it was donned (emergency, training, etc.)

7. Have you ever used any other type of oxygen or compressed air breathing apparatus such as.........

   a. Mine rescue gear? ____________
   b. Firefighting gear? ____________
   c. Scuba gear? ____________
   d. Other (explain) ____________

8. If yes to the above, please explain the circumstance.

9. Have you ever put on and breathed through a FSR? (include no. of time) ________

10. If yes to the above, please give model ____________ and explain circumstances

11. Date of last donning (from records) ________ 12. No. of days ago ________

FIGURE 2.—Interview schedule designed to elicit information about trainee background and prior experience with breathing apparatus.

was necessary to have a way to identify individual records. As a result, field 1 of the data file was designated a key field, and each record was assigned a key number. A key file was then created in the add option of the describe program. This file made it possible to identify each student and the corresponding trial number for a particular treatment.

When the POISE files were created, 31 data fields were delineated to accommodate the information collected. The described fields occupied columns 1 through 438 in the data file. Major fields originally defined include those allocated for student name, identification number, date of training, treatment, trial number, donning sequence, and errors made. Fields for recording critical times, escape times, and narrative comment were also included. An additional 37 fields were added later in order to provide for data gathered during subsequent phases of the study. Included are fields for demographic information, whether or not the subject had followup training, the number of days since his or her last donning performance, and numerous flags to indicate any other types of breathing apparatus the trainee might have been familiar with.

ANALYSIS

It was originally expected that delivery strategy would have an impact upon the subjects first donning trials, but that the act of putting on an SCSR would override and confound the effects of the front- end strategy. It was further expected that the method of giving the brief refresher would influence trainees' performances on the 90-day trials. Specifically, the live demonstration was hypothesized to have the greatest short-term benefit, because that approach, although the same in content as the other approaches, was the only one that offerded the students a live view of the internal components of the case as they were talked through the procedure. Also, it was the only condition that did not have a competing task associated with it. In the area of retention, however, the computer-based training treatment was hypothesized to have the most impact, since it required the highest degree of involvement in getting the necessary verbal information and was followed by a motor performance. Ideally, involvement is expected to foster retention (Johnson (7)). Additionally, it was expected that the computer-based training refresher, being the most thorough, would have a significant influence on subjects performances at their 90-day trials.

INITIAL PERFORMANCE

In order to begin an exploration of the results, subjects performances on the initial trials following instruction were divided into three categories: (1) failures—those who did not get their lungs isolated from the ambient atmosphere, (2) survivors—those who succeeded in getting their lungs isolated, but who did not record a perfect sequence (the criterion), and (3) criterion performers—those who had a perfect sequence on the first trial. Table 1 is a contingency table that presents the observed (or actual) and expected frequencies of performances by each delivery system. The expected frequencies are those that one would expect to occur by chance, given the number of people exposed to each treatment and the number of performances that fall into each of the three categories.

It is instructive to examine the data in the table. Essentially, there were more perfect sequences than expected for the live demonstration, more survivors than expected for the lecture format, and more failures than would be expected for the computer-based treatment. Conversely, there were fewer than the expected number of failures among those who had received the live demonstration, and greater than the expected number of failures among performances following the computer- based delivery. It should be noted that this phenomenon lies in the expected direction: individuals receiving the live demonstration were hypothesized to do somewhat better initially, while those who were more involved would be less likely to forget what they had learned.

A chi-square (X^2) test for independence was applied to performance by treatment condition in order to test the null hypothesis of no association between delivery system and how well subjects did on their initial donning trials. The chi-square value of 13.88 is sufficiently large to enable rejection

TABLE 1. - Chi-square test of performance by delivery (X^2 = 13.88, $P < 0.01$, Cramer's V = 0.212)

Performance	Computer-based		Lecture		Demonstration		Total
	Observed	Expected	Observed	Expected	Observed	Expected	observed
Failure	17	11.9	7	8.7	9	12.3	33
Survivor	20	18.1	18	13.2	12	18.7	50
Criterion	19	26.0	16	19.0	37	26.9	72
Totals	56	NAp	41	NAp	58	NAp	155

NAp Not applicable.

of this hypothesis at the 0.01 level of significance and conclude that there is, in fact, a relationship between the variables which is not due to chance. The magnitude of evidence for the existence of a relationship does not indicate anything about the strength of that relationship, however. Accordingly, Cramer's V, a measure of association suitable for nominal level data, was computed in order to assess how strongly the variables are interrelated. The coefficient, 0.212, represents approximately a 5 pct association. Thus, although chi-square was found to be highly significant, there is only a very weak association between the way in which the 3+3 method was presented to the subjects and how they fared in their initial hands-on attempts.

A second measure of performance immediately following treatment is the amount of time it takes individuals to get the apparatus on. Given what is known about human behavior in fires (Marchant (9)), it is quite likely that most of the time available to don an SCSR in an emergency will be spent in deciding to take action. When one actually begins the task, therefore, he or she should be able to do it rapidly. The most important, or critical, steps are those that are necessary to isolate one's lungs from the ambient atmosphere. Table 2 provides information about how quickly these critical steps were performed by those who were able to do them on the first trial. It should be remembered that those who were not able to complete the three critical steps do not enter into this part of the discussion.

A preliminary analysis of the time data was conducted in order to test the homogeneity of variance assumption. In analyses using the real times, it was found that the null hypothesis of equal variances could be rejected. For this reason, the time measures were transformed into reciprocals (1/X). There is evidence to suggest that reciprocal transformation of time measures is inherently good procedure, because for some subjects the time taken to complete a task might be overly long. A few extreme measures in any one group would increase the variance for a particular treatment, while the variance for the other treatments would not be affected. Transforming the times to reciprocals would tend to make the variances more homogeneous (Edwards (10)). Table 2 includes transformations below the actual means and standard deviations.

As can be seen, those in the live demonstration group required approximately 3 s less (on average) to get their lungs isolated than did those in the other two treatments. An analysis of variance (ANOVA) test for differences between means was performed in order to determine if there was a statistically significant difference in times. The ANOVA model essentially allows a comparison of the magnitude of heterogeneity within samples to the heterogeneity between samples. The rationale is that if subjects are given a treatment that is the same for everyone in their group, but that this treatment is different from the treatment given others, subjects within groups will be more alike on that variable than subjects between groups (Loether and McTavish (11)). All this assumes, of course, that the treatments make a difference in the first place.

The F-ratio (table 3), which indicates the region of a theoretical sampling distribution in which two sample variances would reside, is calculated by dividing the between-group variances by the within-group variances. The larger the F-ratio, the farther out on the tail of a particular F-distribution an

TABLE 2. - Basic statistical data for critical task donning times

	Computer-based	Lecture	Demonstration
Total observations	56	41	58
Students successfully completing critical tasks	39	34	49
Mean critical time, s:			
Actual	18.13	19.12	15.23
Transformation	0.0595	0.0590	0.0705
Standard deviation, s:			
Actual	5.67	8.69	4.74
Transformation	0.015	0.0168	0.0175

TABLE 3. - Summary ANOVA for critical task donning times on transformed scores

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	F-probability
Between	20	.0037	0.019	6.854	0.0015
Within	119	.0325	.003	NAp	NAp
Total	121	.0362	NAp	NAp	NAp

NAp Not applicable.

occurrence would fall. At a certain point in the critical region of the distribution's tail, one is justified in rejecting the null hypothesis that two sample variances estimate a common population variance. At this stage, one may conclude that some type of difference exists between some pairs of groups in the study. As with the chi-square test, however, the existence of a significant F- score does not indicate the reason for that score. A second analysis must be done in order to determine which pairs of group means are significantly different from each other. For the present research, Fisher's LSD (least significant difference) test was used, because it is the most sensitive to small differences between means. Table 2 reveals that two of the possible pairs of means are the cause of the significant F. The pairs are computer-based and demonstration, and lecture and demonstration. Computer-based and lecture were not significantly different from each other.

Tables 4 and 5 present the same information for escape times (the number of seconds trainees required to complete all six tasks in the donning procedure) that table 2 and 3 contain

TABLE 4. - Basic statistical data for escape times

	Computer-based	Lecture	Demonstration
Total observations	56	41	58
Students successfully escaping	25	23	41
Mean critical time, s:			
Actual	65.28	63.94	53.49
Transformation	0.0170	0.0166	0.0203
Standard deviation, s:			
Actual	24.88	18.52	15.76
Transformation	0.0052	0.0037	0.0059

for critical times. These tables are self-explanatory and will not be discussed in detail. It should be noted, however, that the degrees of freedom for the within- subjects source of variation is 86 rather than 119, as given in table 3. Degrees of freedom for within-subjects variation are calculated by taking the number of subjects minus the number of groups. The difference in degrees of freedom, then, reflects the fact that fewer people were able to complete all the procedural tasks than were able to complete just the critical steps. It might also be noticed that the total number of criterion performances listed in table 1 is different from the total number of people recorded as successfully escaping in table 4. This is because a different logic was used in compiling the data. The criterion was a perfect performance. However, some subjects completed all six tasks, thereby receiving an escape time, but did some of the tasks out of order. Hence, their initial performance was not their last, or criterion performance, although they were considered to have escaped.

A third measure of performance is errors. Table 6 provides an accounting of errors made on each task by treatment condition. An examination of the table shows that the two areas where people seemed to have the most trouble

TABLE 6. - Portion of each group making errors in initial donning trial by delivery, percent

Error	Computer based	Lecture	Demonstration	X^2	P
Loop	1.8	9.8	3.4	3.73	0.155
Activate	19.6	14.6	10.3	1.95	.377
Mouthpiece	5.4	12.2	5.2	2.19	.333
Noseclip	7.1	9.8	1.7	3.12	.210
Goggle	21.4	26.8	19.0	.88	.644
Strap	12.5	22.0	5.2	6.29	.043[1]
Hat	7.1	14.6	8.6	1.64	.441

[1]Significant at or below P <0.05.

were in activating the oxygen and in donning the goggles correctly. Both of these omissions are relatively serious. Failure to activate the chlorate candle on the Draeger means that the apparatus does not provide an initial burst of oxygen that the miner uses while activating the bed of potassium superoxide with his or her breath. The bed of potassium superoxide must then be activated by breathing in and out of the air bag several times without the benefit of a fresh oxygen supply. Rebreathing one's own air while waiting for the bed of potassium superoxide to begin delivering oxygen presents the danger of oxygen depletion, which would lead to unconsciousness. In the same vein, failure to put the goggles on properly would result in eye irritation in heavy smoke, and might impair a person's ability to escape. A series of significance tests were performed on the errors reflected in table 6 in order to ascertain if there were any differences in proportions of errors by treatment. As can be seen, the only chi-square score large enough to justify rejection of the null hypothesis of independence was in the number of errors made in trying to adjust the neck and waist straps.

TABLE 5. - Summary ANOVA for escape times on transformed scores

Source	Degrees of freedom	Sum of squares	Mean square	F-ratio	F-probability
Between	2	0.0003	0.0001	4.973	0.0090
Within	86	.0023	.0000	NAp	NAp
Total	88	.0026	NAp	NAp	NAp

NAp Not applicable.

NINETY-DAY TRIALS

As with the initial trials, subjects performances 90 days after having received their hands-on training were divided into failures, survivors, and those recording criterion sequences. Table 7 presents the observed and expected frequencies of performances by delivery strategy. The effect of front-end treatment was expected to disappear following the trainees hands-on experiences. The chi-square test for independence suggests that this is what happened. An unexpected finding is that the brief refresher given 30 days before the students were brought back in had minimal impact upon those who received it. As can be seen in table 8, there is almost no difference between observed and expected performance in any of the categories. Although not anticipated, the absence of a refresher effect on performance has a straightforward explanation: (1) the researchers deliberately kept the refresher presentation at the level one might reasonably expect to be given at a monthly safety meeting, (2) the refresher was administered to allow a long period of forgetting under the assumption that if workers received these presentations monthly, the worst case would be a disaster just before the next scheduled refresher, and (3) everyone in the sample had gotten the best hands-on training possible just 90-days before these trials. Therefore, most people did relatively well, refresher or not.

Time is the second indicator of training effectiveness examined in this section. Table 9 shows comparisons between how rapidly subjects were able to complete their criterion trials and how they did when they were recalled 3 months later. As the left half of the table indicates, 58 of the 72 trainees were able to complete the tasks necessary to isolate their lungs. The standard deviation for their 90-day trials reveals that not only had their average critical time increased, but that they were much more variable in the amount of time taken to complete the tasks. This finding was expected, and reflects what is known about skill degradation: forgetting invariably takes place over time, especially the forgetting of nonroutine tasks. A repeated-measure ANOVA test for differences between the two means resulted in a significant F ratio.

The right half of table 9 follows a different logic in the compilation of data, and must be interpreted cautiously. The mean times and standard deviations denote how all 72 subjects in the sample did from the time their hands touched the case of the SCSR until they signalled that they were ready to escape. Since the comparisons are being made between criterion trials and 90-day performances, the numbers under the heading original are derived from a complete and perfect sequence achieved by each trainee. The numbers under the heading 90-day are, with the exception of 13 individuals, obtained from incomplete and imperfect sequences. The difference between the two means in this case is not statistically significant, but it is qualitatively significant.

TABLE 7. - Chi-square test of 90 day trial performance by delivery ($X^2 = 6.40$, $P = 0.1712$, Cramer's $V = 0.218$)

Performance	Computer-based		Lecture		Demonstration		Total
	Observed	Expected	Observed	Expected	Observed	Expected	observed
Failure	8	4.7	4	4.7	2	4.7	14
Survivor	14	15.0	14	15.0	17	15.0	45
Criterion	2	4.3	6	4.3	5	4.3	13
Totals	24	NAp	24	NAp	24	NAp	72

NAp Not applicable.

TABLE 8. - Chi-square test of 90 day trial performance by comparing refreshed and nonrefreshed subjects ($X^2 = 0.892$, $P = 0.6401$, Cramer's $V = 0.1113$)

Performance	Refreshed		Nonrefreshed		Total
	Observed	Expected	Observed	Expected	observed
Failure	7	7.0	7	7.0	14
Survivor	21	22.5	24	22.5	45
Criterion	8	5.6	5	5.6	13
Totals	36	NAp	36	NAp	72

NAp Not applicable.

TABLE 9. - Repeated measures of critical and secondary donning times

	Critical Original	Critical 90-day	Secondary Original	Secondary 90-day
Observations	58	58	72	72
Mean, s:				
Actual	15.22	23.76	54.68	66.20
Transformation	0.069	0.015	0.020	0.018
Standard deviation, s:				
Actual.	3.690	15.56	16.48	33.95
Transformation.	0.052	0.020	0.005	0.007
F ratio:				
Actual	20.14	NAp	10.77	NAp
Transformation.	49.97	NAp	2.24	NAp
Probability.	NAp	<0.01	NAp	<0.05

NAp Not applicable.

A series of ANOVA tests were run to determine the net effect of the treatment and refresher factors on both critical and secondary donning times. The proportion of variation explained by the additive effects of training strategy and whether or not subjects had received a refresher presentation was negligible, and will not be discussed further.

The third variable of interest from the 90-day trials is the percent of each group making at least one error. Table 10 shows that, as with the initial attempts after instruction (see table 6), the trainees consistently had difficulty activating the oxygen and donning their goggles. Strap adjustment was also a problem at the 3-month interval, especially for the computer-based training subjects, and resulted in the only significant chi-square score in the table. Adequate strap adjustment is important, because the SCSR must be secured in order to allow the maneuverability necessary to enable a miner to escape once he or she has succeeded in isolating his or her lungs from the ambient atmosphere.

TABLE 10. - Portion of each group making errors in 90 day donning trial by delivery, percent

Error	Computer based	Lecture	Demonstration	X^2	P
Loop	16.7	0.0	8.3	4.36	0.113
Activate	20.8	16.7	8.3	1.50	.472
Mouthpiece	12.5	16.5	4.2	1.27	.531
Noseclip	4.2	0.0	0.0	2.03	.363
Goggle	25.0	20.8	20.8	.16	.963
Strap	66.5	12.5	20.8	15.84	.0004[1]
Hat.	20.8	12.5	0.0	5.34	.069

[1]Significant at or below P<0.05.

DISCUSSION

This paper has dealt with one of the most critical and nonroutine of all mine health and safety skills: the ability to put on an SCSR in the event of an emergency. The results clearly illustrate that donning an SCSR is not easy, and that miners must have hands-on training if the apparatus is to be of any benefit when circumstances dictate its use. What the content of this training should be has been resolved through extensive field testing: the new 3+3 method has shown itself to be an efficient and highly effective procedure. The question of how the 3+3 method should be delivered has been addressed here: it seems to make little difference (Zsiray (12)) as long as the content is presented thoroughly and systematically, and followed up with hands-on experience. The problem of how often, and at what level, miners should be refreshed is still open to exploration.

As was mentioned in the "Experimental Protocol" section, there was no overlearning involved in the initial training. Once a subject had reached criterion, he or she was dismissed. There is evidence that overlearning increases retention, and that had the subjects in this study been required to repeat their criterion (or perfect) performances several times, there would have been fewer failures and fewer errors on the 90-day trials (Hagman and Rose (8)). What is not so evident is whether anything short of relearning the task, in the same way it was learned the first time (by hands-on training), would have resulted in significant differences between refreshed and nonrefreshed trainees on any of the performance measures used here (Johnson (7)).

There are some interesting implications in both of these observations. First, if overlearning is the key to proficiency in SCSR donning, there must be a substantial front-end investment of both time and effort on the part of trainers and trainees alike. With the time constraints of annual refresher training, and the scarcity of either training models or real SCSR's used for training, the logistics of making this investment become challenging. A hands-on session, with remedial instruction following the trial, takes from 5 to 10 min per trainee, and requires the participation of at least one trainer. Cleaning, sanitizing, and repacking the apparatus in order to get it ready for the next student entails another 5 min or more (depending upon the model being used). When the overtraining factor is added in, this time cost increases significantly. Second, if hands-on relearning is the key to skill maintenance, it may have to be done more often than once a year. Almost 20 pct of those recalled for their 90-day trials failed by not completing one or another of the critical tasks. The encouraging note is that almost 20 pct were still able to do a perfect sequence. In a mine fire or explosion, however, a trainer undoubtedly wants no failures, and many more people in the perfect category. This goal may well require giving at least some of the workforce additional training during the year.

Given the findings of this series of studies to date, there are some obvious areas for further research. First, of course, the forgetting curve needs to be charted in order to assess the magnitude of skill degradation between one annual refresher class and the next. Second, the benefits of overtraining must be investigated. Third, a determination should be made as to what kind of interim refresher, up to and including hands-on relearning, would be effective in helping miners retain their proficiency in donning the SCSR. Fourth, and most important, a device should be developed that would allow some of the training burden to be assumed outside the traditional 8-h annual refresher session (if that is needed). There are at least two components to this device: (1) an instructional package (perhaps a videotape and short computer-based training program) that would enable miners to take self-paced remediation; and (2) a simple, durable, hygienic, inexpensive dummy SCSR that would have the adaptability to be practiced with in situations ranging from annual refresher training classes to preshift safety talks.

In the coming months, the Bureau will be addressing each of these problems. The aim is to discover a training regimen that will allow miners to achieve and retain proficiency in donning SCSR's while not intruding unduly upon a mine's production activities. It is expected that a major focus of this future research will be on the development of a means for integrating certain aspects of SCSR training with established practices such as scheduled fire drills and walking the escapeways. In this way, not only will SCSR training be strengthened, but the routine preparation for emergency escape procedures will take on an added dimension.

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THE WORK CREW PERFORMANCE MODEL: LINKING TRAINING, ASSESSMENT, AND PERFORMANCE

By William J. Wiehagen,[1] Michael J. Brnich,[2]
Henry J. Kellner,[3] and Warren E. Lacefield[4]

ABSTRACT

This paper discusses a conceptual model developed by the Bureau of Mines for evaluating the training and performance of underground equipment operators. The need for such a model is demonstrated by a review of the limitations of present industrial skills training and performance evaluation procedures, particularly as these relate to cost-justifying performance improvement strategies. A computer simulation program to profile the performance of underground shuttle car operators was developed. Implications are drawn for use of the simulation program as a practical diagnostic and prescriptive tool for structured on-the-job training, job design, supervision, and management policy. Current avenues of joint research with a cooperating coal company to apply and further develop the model are discussed.

INTRODUCTION

McKeon (1)[5] estimates that organizations in the United States annually spend at least $137 billion for training. This training, commonly referred to as human resource development (HRD), is broadly intended to enhance the profitability of organizations and improve the quality of worklife (2). While the training literature abounds with testimonials regarding the value of HRD efforts, few studies have attempted to tie that training specifically to the performance of the workers and to ways improvements in performance translate into additional profits and/or cost savings within their organizations (3). As Cascio (4) points out, "the adage 'millions for training but one cent for evaluation' may be an exaggeration but is not altogether an untrue characterization of many organizations."

Conducting tightly controlled studies of training value is a formidable and expensive task for any organization and the shortage of such studies is certainly understandable. Why, for example, should a company that has just spent $10,000 defining needs and developing and conducting a well-thought-out training program spend additional dollars for a structured evaluation that goes beyond perhaps a questionnaire assessing the reaction of participants? Simply defining the value of additional information provided by the formal evaluation is, by itself, a speculative and somewhat qualitative task. If one cannot define the benefit, then there is little incentive to spend the money. For those organizations that rely on informal on-the-job training (OJT), either for the sake of tradition or economies of scale, there is little chance that money will be allocated for evaluation. However, money saved by taking training outcomes on faith (i.e., not establishing empirical links between training and profit) oftentimes results in HRD activities being the first to be cut when profits decline (4). As Campbell (5) points out, the recurring admonition to 'evaluate' training programs is a gross misrepresentation of the empirical question. It strongly implies a dichotomous outcome; to wit, either the program has value or it

[1]Supervisory industrial engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.
[2]Mining engineer, Product Research Inc., Pittsburgh, PA.
[3]Industrial engineering technician, Pittsburgh Research Center.
[4]Research psychologist, Pittsburgh Research Center.

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

doesn't. Such a question is simple-minded, unanswerable, and contributes nothing to practical or scientific understanding.

These remarks imply that more useful and realistic training and performance assessment methods need to be developed. More attention should be given to the use of dependent variables that reflect cost-benefit components of investments in performance improvement strategies (training, job design, environmental modification, supervision, etc.) within the context of organizational performance. Modeling an individual worker's performance within the context of the work crew and linking that performance to organizational accomplishment is one approach that appears to hold much promise from both the viewpoint of the individual and the organization.

MINE TRAINING ISSUES

Safety and skills training activities have long been recognized as essential elements in programs for reducing injuries and improving productivity within the minerals industry (6). Unfortunately, as in other work organizations as well, the impact of mine training investments on injury rates and productivity is largely unknown.

Most mine managers recognize that training is a fundamental condition of organizational life. But the failure to allocate the resources to establish the connection between training outcomes and organizational goals (e.g., improving profit, reducing injuries), over time, diminishes the training function and its respect within the organization. This often leads to a cyclical pattern of training investments paralleling the profit curve. Training becomes a useful notion for creative ways to spend or invest money when profits are high. Likewise, when profits decline, many organizations view training as an expendable item since it does not pay wages and can be purchased if really necessary.

Perhaps the problem is not so much the role of in-house training or the philosophies of management, but rather more with how the effectiveness of training is demonstrated. Again, the issue is not whether to evaluate, but perhaps what are suitable criterion outcome measures (i.e., dependent variables) when evaluation is done. Typical bottomline evaluations of training in the mining environment (e.g., Morris (7), Adkins (8)) tend to focus on improving both profit (measured through productivity) and the quality of worklife (measured through injury frequency, severity, and health risk). Often, however, these measures are simply too generic and broadly defined for single-site studies to be useful in justifying long-term, performance improvement programs. The following discussion illustrates these points.

INJURY DATA

A fundamental problem with injury data as measures of training effectiveness is the appearance that the attempt is to teach miners not to have accidents. In fact, injuries are rare events for particular mine sites. For example, the expected frequency rate for a lost-time injury in an underground coal mine is approximately 0.06. This means that an underground mine employing 100 miners would be right at the national average if 6 of those miners sustained a lost-time injury for a given year. With such small samples and expected frequencies, even if statistically significant changes could be shown, the generalization of the results would be suspect at best. Moreover, using injury data collected long after training to measure the effectiveness of that training would imply a belief that the treatment (whatever it was) would have more impact on performance than extended practice and day-to-day reinforcements that are part of the normal work environment. This "necessary but not sufficient" rule of training has been rediscovered and described by many researchers and practitioners.

Organizations do depend on bottomline evaluations and rightfully should expect training to influence injury rates. However, proving this impact is another matter (9), especially where experienced miners and machine operators are involved. The basis for HRD investments needs to be more in tune with real purposes for training, e.g., to develop a capability that does not yet exist or maintain and reinforce an existing high level of skill.

For example, Adkins (8) conducted an aggregate assessment of mine safety training on the frequency and severity of lost-time injuries. Using first aid training as a case in point, one could reasonably hypothesize that increasing the investment in first aid training should have some effect on the severity of mining injuries. However, in Adkins' study shown in figure 1, no clear relationship existed at the aggregate level to support this hypothesis. In fact, until the characteristics of successful training programs are determined, the data provide little insight as to why training did or did not appear valuable.

The data in figure 1 show that there is considerable variance from one year to the next in injury rates after adjusting for production differences. Clearly, concomitant changes in the number of training courses offered do not appear to be significant factors helping to explain this variance. While one could argue that it is not what you do but how you do it, the facts remain that injury data are (1) too broad and too easily influenced by other effects and (2) too rare for easy capture and explanation using simple analytical methods.

Many alternative factors that could markedly influence injury rates other than training could be advanced. For example, a mining firm could significantly reduce its injury rate simply by working with the local medical and mining communities to encourage individuals to return to the work site at the earliest possible date. Differential utilization of human factors technologies to reduce or eliminate the consequences of human error would influence the exposure of

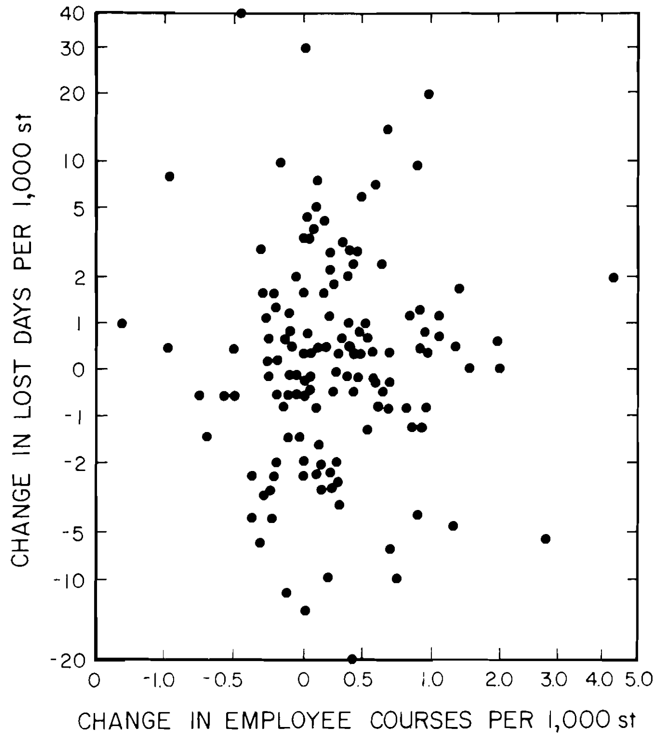

FIGURE 1.—Changes (1973 minus 1972) in lost days as a function of rates of training (*1*).

miners to environmental and task-specific hazards at the work site and hence the likelihood of injuries. On the other hand, a mining firm could have an outstanding training program solidly based on job skills and worker competence, yet still show no statistical changes in injury patterns. This could be due to an already low injury rate or to the law of diminishing returns from training or practice, or any one or combination of other possible explanations completely divorced from training issues. These arguments simply point out the difficulties in designing studies focusing upon injury rates. Even well-designed research efforts can lack the resolution necessary to separate effects due to training and those due to other intervening variables.

PRODUCTIVITY DATA

Mine productivity measures—tons of coal per shift or per full-time equivalent employee—are as problematic if not more so than injury and loss time measures when used as assessments of training effects. A key problem is that productivity measures are often based on estimates of efforts rather than on calculations of actual costs of producing. Too often, only aggregate measures are available. Frequently, this information is based on poorly organized data and/or merely reflects static, cross-sectional conditions at specific points in time. Moreover, such measures are notoriously insensitive to differences in training and provide no help to identify areas where human performance could or should be improved or where specific methods for upgrading performance might be better employed. They provide no clues as to whether a performance improvement strategy should be based on better teacher training, modified training content and/or methods, more frequent skill maintenance training, increased supervision, job analysis and redesign, better equipment, or modified company policies. Compounding the problem is the observation that actual improvements in production and safety are rarely the result of a single treatment implemented in isolation.

For example, a study conducted by McDonnell Douglas (Morris (7)) under contract with the Bureau of Mines, examined production rates of continuous miner operators who participated in a highly structured training program utilizing a part-task trainer in conjunction with structured OJT. Generally following Kirkpatrick's model (10), four different training outcomes were studied: (1) reaction (questionnaire), (2) learning (pretests and posttests), (3) behavior or training transfer (section supervisor evaluations), and (4) results (productivity, downtime, and product quality). These researchers reported significant improvements in organizational performance (fig. 2) as well as favorable employee and supervisor reactions.

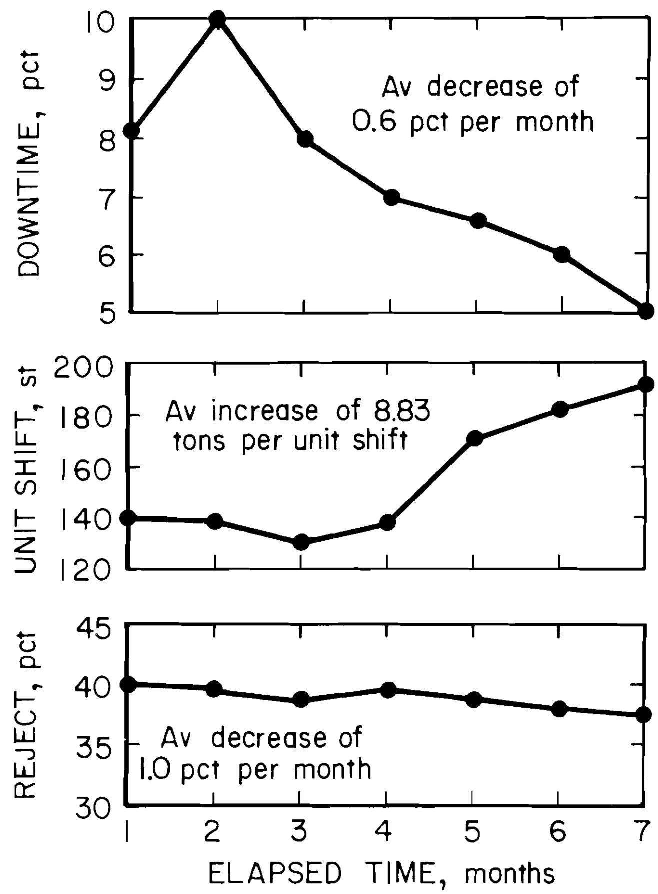

FIGURE 2.—Effects of highly structured training program on downtime (top), productivity (middle), and product quality (bottom).

In spite of these positive findings, limitations in using these data as measures of training effect include the following:

1. *Performance of other crew members.*—For example, the miner operator, independent of his or her skill level, cannot (and should not) mine coal if the roof bolting operation is not providing a secure and safe work environment.

2. *Machine maintenance.*—Factors such as the age of equipment and policies and practices regarding preventive maintenance also influence downtime, productivity, and quality.

3. *The effect of supervision.*—In the study (7), section supervisors also received instruction regarding operation of the equipment and were acutely aware of the type of training provided to their employees. In part, this training feature (a good management practice highlighted by the needs assessment procedure) helped assure the success of the program as reflected in the data.

4. *Possible changes in the mining environment.*—Changing roof conditions as mining operations progressed could easily have been a more persuasive alternative explanation for the data trends shown in figure 2.

This list represents only a few of the possible threats to the validity of an experiment like this one. Many arguments like these can be (and were) addressed by good research design and prior attention to possible intervening factors. Nevertheless, the need for efforts to control other factors that can affect traditional measures, such as safety and productivity, introduces many difficulties when attempting to use these variables as measures of training effectiveness.

The uncertain impact of training on classic measures of organizational performance calls into question traditional methods for evaluating training and cost-justifying performance improvement strategies. Production and safety statistics collected at the job site for the purpose of assessing organizational accomplishment are not useful indicators of training effectiveness unless they can be broken down and shown to be logical antecedents of still more specific sets of employee competencies and skills upon which training objectives, instructional methods, and performance evaluation techniques are based. This is not usually the case. Instead, job site measurements too often tend to reflect not only the performance of an individual machine operator but also variability in the work environment (e.g., roof condition, seam height, etc.), the condition of machinery and equipment, the performance of other crew members, the availability of supplies, and so on.

What is needed for measurement and evaluation purposes are cost-related variables that reflect individual competencies but also are relatively independent of day-to-day circumstances. Such variables would be related to the primary job accomplishment defined for a specific job role or position. For example, the primary job accomplishment of a shuttle car operator might be described in terms of productivity, as *hauls 300 tons per shift*. However, a better measure is, simply, *minimizes the miner operator's waiting time for an empty shuttle car*. The problem can then be defined in terms of operations research and performance improvement strategies (including training and evaluation). A cost-benefit assessment of operator skill would be based on observing those activities under the direct control of the equipment operator that increase or reduce waiting time for the miner operator. An analysis of error patterns and associations between errors and factors related to injuries, downtime, and property damage becomes a critical element in such an assessment. These considerations provide the basis for the work crew performance model described in the following section.

WORK CREW PERFORMANCE MODEL

The work crew performance model (WCPM) seeks to integrate procedures for conducting job analyses, evaluating worker performance, and using cost information as a basis for decision making within the context of organizational goals (e.g., profit, safety, growth). Since profit, for instance, is directly tied to production cost per unit, key variables used to define, measure, and evaluate worker performance should emphasize those specific behaviors that can have marked impact on the unit cost. Of specific interest are behaviors under an individual crew member's control that can be described in terms of deviations from a criterion (e.g., normative error profiles or prescribed proficiency standards) and corresponding probabilities of downtime, injuries, and/or damaged property. In effect, the WCPM seeks to focus attention on the criticality of performance errors for individual jobs within the work crew. By successfully modeling an individual worker's performance and linking that performance to the accomplishments of the work crew, the WCPM provides a potentially strong empirical foundation on which to base decisions concerning improvements in training, supervision, job design, management policy, or modifications to the working environment (11).

Implementation of the model includes provisions for

1. Job definition through task, skill, context, and performance analyses.

2. Observational techniques to establish performance baselines useful for the conduct of performance evaluations or measuring learning outcomes.

3. Cost linkages between performance profiles and resultant costs (measures of injuries, downtime, and maintenance overhead).

4. Intervention strategies concerning improvements in training, supervision, job design, management policy, or modifications to the working environment.

This approach is unique in that it seeks to integrate these typically exclusive provisions within a work organization.

For example, common methods used to define standard operating procedures, establish job performance requirements and evaluate operators' work behaviors have been based primarily on activities deemed necessary to accomplish the job, i.e., checklists of appropriate or desired behaviors. Such lists of behaviors have been prepared by many developers and users of industrial training programs but are typically divorced from day-to-day records of production downtime, lost-time injuries, and maintenance overhead. The WCPM provides a framework for integrating various types of data and using information from a variety of sources to guide decisionmaking. An integrated approach also allows the model to be used as an evaluation tool with veteran as well as novice equipment operators.

ASSUMPTIONS

The WCPM rests on a set of assumptions about the nature of the worker and the job that need to be made explicit. A key assumption is that performance errors lie outside the person. This is to say that for the most part individuals make errors without intent to incur personal injury, induce downtime, or damage property. In other words, employees come to work to be productive. Performance differentials between individuals are often nebulous and ill-defined (12). The model does not simply attempt to classify individuals as exemplars or average performers, but seeks to attend to those common errors or differences in error profiles that can markedly affect the unit cost. Use of the model to profile operational errors and the selection of an intervention strategy are tempered by making the following realistic assumptions regarding work:

1. All individuals will make errors, regardless of the level of training or experience. Error rates of individuals are dependent upon a host of things that may or may not relate to the quality of initial training.
2. Error rates can be observed, measured, and managed. Although there may be cognitive components such as errors in judgment and decisionmaking, resultant behaviors and outcomes can, in most cases, be observed and quantified in terms of cost consequences to the organization and the individual.

These assumptions are the basis for the WCPM and parallel research work conducted by the U.S. Department of Transportation to develop methods for visual detection and discrimination of driving errors committed by individuals driving while sober versus errors committed by those driving under the influence of alcohol (13).

Thus, at a minimum, the WCPM can be thought of as a visual detection method to identify critical components of complex job performances such that wide differentials in performance for high-consequence tasks are identified and treated. Viewed this way, it is possible that the total set of errors of the exemplar may exceed the error rates of average operators, but the types of errors committed may be quite different.

MODEL COMPONENTS

Taking the operation of a shuttle car in an underground coal mine as an example, a job analysis might reveal as many as 40 to 80 specific activities an operator is to perform in order to fulfill the job requirement. The result of the analysis would be organized into hierarchies of task and subtask categories, with descriptions of the skills involved and the typical working conditions for each task. A performance criterion for each category, based on typical, practical, or ideal work standards, should also be included in the analysis (14).

Job Definitions

Examples of major task categories for shuttle car operation might include preshift inspections, tramming, loading, idle-time activities, etc., whereas a subtask in the tramming category might be switching the headlights to the opposite direction after reaching the continuous miner. However, the practical utility of these lists is limited without associated information about the relative frequencies of these behaviors and the probabilities that deviations in performance will have a direct and important impact on safety and on the unit cost of the underground mine section. For these and other reasons, a comprehensive model of worker or work crew performance must look ahead to the consequences of performance errors and the accumulated effects of these consequences on organizational goals within which work performances take on meaning.

Behavioral Observations

Behavioral observation is a technique for systematically monitoring performance over a period of time and during typically variable work conditions. This procedure can provide detailed and accurate estimates of proficiency but requires observers with knowledge of the nature of the job or task and experience to make sound judgments about the quality of observed performances. In addition, observers should be persons whose presence is unobtrusive in the workplace. In underground mines, the supervisor or section boss is the individual best situated to observe members of the work crew.

Unfortunately, frontline supervisors have limited resources for the evaluation of performance. Observing and rating an operator's performance on 40 to 80 steps repeatedly during day-to-day operations strains the supervisor's time and opportunity and may not efficiently focus attention on those areas of performance that most significantly affect unit cost (including safety). As a result, supervisors often evaluate performance at the level of tasks rather than subtasks, e.g., the conduct of a preshift inspection (10-25 steps), tramming (10-20 steps), loading (8-12 steps), dumping (10-15 steps), etc.

Assuming enough observations are made, evaluating performance at the task level can yield good estimates of proficiency, adequate for administrative purposes and for establishing benchmark criteria and charting changes in proficiency as a function of experience or training. Too often, however, this sort of aggregate information is of little value to the trainer or the employee without further attention to the components of proficient performances and the identification and consequence of critical errors. It is only through an increasing awareness of mistakes and methods to avoid them that workers become able to assess and improve their own behavior on the job. The WCPM provides a rational and efficient means for identifying costly errors and relating these to production variables and matters of safety and health.

Cost Linkages

A key issue for WCPM development concerns the identification and ranking of observable behaviors that affect unit cost. A useful performance evaluation model would account for correlations and causal relationships among observable behaviors and general competencies that contribute to reductions in the unit cost and lead to improvements in traditional measures of safety and productivity. Such a model would not only identify errors, but also suggest the monetary value of concrete solutions that could be implemented to enhance performance via the elimination of costly errors. In the case of the shuttle car operator, the goal is to minimize the amount of time that a continuous miner operator has to wait for an empty shuttle car. Factors that have negative impacts on waiting time include errors (behaviors) that, only as a matter of chance, lead to injuries, downtime, excessive maintenance, and property damage. Once these factors are identified, the task becomes one of (1) enhancing supervisor's abilities to discriminate between significant and nonsignificant performance errors by associating those errors with their cost consequences and (2) identifying performance improvement strategies to reduce the frequency of costly errors at the work site. The latter might involve job redesign, supervision and coaching, formal training and OJT, corporate policy or modifications to the work environment.

Computer Simulation

A computer simulation was developed for use in profiling and evaluating shuttle car operator performance. The simulation is designed to accept input on operator performance collected during observations at the work site. The simulation begins with a series of questions about each activity associated with shuttle car operation. The activities are grouped under six major task categories: preshift activities, tramming, loading, dumping, idle-time activities, and end-of-shift activities. After completing one sequence of questions about one activity, the user is prompted to respond to the next sequence. The simulation requires the user to respond to all questions about each activity. The user is prompted to check entries and make changes or correct errors within each sequence of questions before advancing to the next activity area.

For each shuttle car operation step, a probability is assigned to reflect the likelihood of a costly consequence if that activity is not performed correctly. These probabilities were derived through observations, time-and-motion studies, and discussions with experienced shuttle car operators and supervisors. For each step, a downtime value also is assigned to reflect the potential production loss associated with the occurrence of a costly error. Based on descriptive data about specific operations at the mine site and on input performance data (from observations) as well as the probability and cost value associated with each activity, the simulation estimates the number of costly errors that an operator may incur over a specified time period. Likewise, total estimated downtime for the period, along with anticipated resultant costs, can be predicted.

Two versions of the computer simulation have been written in FORTRAN. One operates on a Digital Equipment[6] VAX minicomputer while the other is designed to operate on IBM and IBM compatible personal computers. Both versions of the simulation prompt the user for the name of the shuttle car operator and for information about the operator's performance by asking concise questions about each specific activity. The user is offered six response choices and selects the one that most accurately reflects his or her own level of performance. Alternatively, the section supervisor can use the observation system and enter this information directly as data about individual employees. The user is then told what error probability and production downtime values have been assigned for each particular operation and is offered the opportunity to modify one or both of these values. Figure 3 illustrates a typical question sequence.

```
TASK AREA:  Pre-Shift Activities
Activity:   Checks cable snub location

        1.   Never ( 2% )
        2.   Seldom ( 30% )
        3.   Half time ( 50% )
        4.   Nearly always ( 70% )
        5.   Always ( 98% )
        6.   Does not apply

Please select a number and press return key ==>

Error probability is 1/100
Do you think it is correct ? (type Y or N) ==>

An error will cause 17 minutes of delay
Do you think this is correct? (type Y or N) ==>
```

FIGURE 3.—Typical activity question sequence.

[6] Reference to specific products does not imply endorsement by the Bureau of Mines.

After the questions related to shuttle car operation have been answered, the simulation prompts the user to enter the number of shifts the simulation is to run. Next, the user is asked for the number of loads the operator being studied hauls on an average shift. Finally the user is asked to input the average cost of a lost minute of production downtime at his or her mine. (The default value is $12 per minute.) At this point, the simulation input is complete and the routine begins processing the information entered. Once processing is completed, the output is available as a screen display, text file written to disk, or as a printout for later study.

The output text consists of four pages. The first is a summary page (fig. 4) that provides information on the following variables:

1. Total number of shifts.
2. Total number of trips.
3. Estimated number of errors.
4. Estimated number of costly errors.
5. Estimated total downtime (in minutes).
6. Estimated monetary loss (in dollars).

The remaining output provides a detailed analysis of the simulation run that lists each shuttle car task area and activity and indicates the probable number of errors and number of costly errors projected for that activity. The information provided in the detailed output (figure 5) consists of:

Column 1. Activity description.
Column 2. Performance rate (rank assigned by observer).
Column 3. Accident-error (probability of costly error occurring assigned to each activity).
Column 4. Number of errors made (estimated totalerrors).
Column 5. Number of accidents happened (est. costly errors).
Column 6. Downtime loss (in minutes).

SHUTTLE CAR OPERATOR PERFORMANCE

Operator: Paul
Total shifts: 100

Total tramming, loading, and dumping trips:	5000
Estimated error total:	44460
Estimated total costly errors:	78
Estimated total downtime (minutes):	84
Estimated total downtime loss ($):	3770

See next page for detail

FIGURE 4.—Typical summary printout.

This detailed analysis permits the user to rank errors and establish a cost base for a proposed treatment. Possible performance improvement strategies might consist of combinations of training, environmental modifications, and changes in job design, equipment, supervision, or management practices.

TRAMMING OPERATIONS

ACTIVITY	PERFORMANCE RATE	ACCIDENT /ERROR	ERROR MADE	ACCIDENT HAPPENED	DOWNTIME LOSS(MIN)
Trams appropriately for haul road conditions; rounds corners smoothly; uses care to prevent banging ribs.	.70	1/1800	1489	0	0
Trams carefully watching for CM cable and water hose, roof-bolter, and other cables.	.70	1/100	1192	3	51
Makes certain there is sufficient cable on reel to reach CM.	.98	1/1500	190	0	0
Slows shuttle car when approaching the CM.	.50	1/1000	2200	2	20
Stops behind CM when the boom is low.	.98	1/1000	200	0	0
Watches for the ventilation curtain.	.70	1/5000	1835	0	0

FIGURE 5.—Typical detailed printout: Tramming activities section.

EXTENDING AND APPLYING THE WCPM

The development of the WCPM, first for shuttle car operations and later for other mining machinery and work crews, is part of an ongoing Bureau program of research. This paper is the second in a planned series of research reports describing the development and validation of model components and potential applications for training, supervision, job design, and management policy.

In 1987, with the support and cooperation of a medium-sized coal company in eastern Kentucky, Bureau researchers completed an initial time-motion study of underground shuttle car operations in these particular mines. A thorough job analysis was prepared and shared with experienced equipment operators, trainers, supervisors, and other experts. These persons assisted in the identification of critical activities and errors with high likelihoods of downtime, injury, or otherwise costly consequences. A behavioral observation system has been developed and tested to provide an efficient way to gather onsite performance data for analysis and proficiency estimation. In addition, preliminary studies of mining company records and data collection methods are underway to examine relationships among operator, equipment, productivity, and safety variables. The WCPM computer simulation has been field tested during regular and special training sessions and revisions are planned to improve the speed, interactivity, and instructional potential of the program. Other components for implementing performance improvement strategies that have extended duration and involve structured training, OJT, supervision and coaching emphasis, and followup activities are being assembled.

These developments and extensions of the WCPM are leading to a full-scale, longitudinal study and field test in several mines with the cooperation of several shifts of miners, their supervisors, and the training staff at the eastern Kentucky site. This study will involve three 3-month periods of behavioral observation and productivity data collection and two different training intervention strategies. It is hoped that this work will further demonstrate the validity of WCPM concepts and will provide supervisors and trainers with useful tools to assist equipment operators improve safety, proficiency, and productivity in their working environments.

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ROOF AND RIB HAZARD RECOGNITION TRAINING USING 3-D SLIDES

By Edward A. Barrett,[1] William J. Wiehagen,[2] and Charles Vaught[3]

ABSTRACT

Unplanned falls of roof and rib have been historically a leading cause of work-related deaths in the underground coal mining industry. One possibility for a reduction in roof-fall fatalities is to improve the ability of miners to recognize salient visual cues associated with geologic or mining-induced irregularities. Such perceptual skills are generally acquired through underground experience and/or training and, consequently, will vary considerably among miners. The hazard recognition skills of underground workers may be improved in the classroom through effective training if instructional aids are used that realistically portray the actual mine environment. Because stereoscopic (3-D) slides are a high-fidelity medium that can accurately represent real underground conditions, they are an excellent proxy for miners to learn to recognize the characteristics of unstable mine roof and rib.

Even though worker knowledge of ground hazards may be extensive due to years of mining experience, workers may not be competent in assessing potentially hazardous conditions. The truly competent miner in the area of ground hazard awareness must have the ability to perceive, recognize, and correct dangerous groundfall conditions.

The state-of-the-art of 3-D photographic equipment and procedures for documenting underground roof and rib conditions has been significantly advanced by the Bureau of Mines. Most mine training departments can now independently provide and regularly update their own 3-D instructional materials at minimal cost.

INTRODUCTION

The roof and ribs of an underground coal mine confront management and workers with a transient situation that requires constant vigilance. For example, slickensides or slips (smooth, polished, and sometimes striated surfaces that result from movement of rock on either side of the surface) are one of the most common geologic hazards in coal mine roof. The normal roof control plan may provide for adequate control of small slickensides extending less than 3 ft. However, large slickensides must receive additional support, such as wood headers, straps, extra bolts, etc. Slips may be exposed during mining or develop at a later time, but in either case, they are potentially very dangerous and should be treated with extreme caution. Remedies for this type of roof hazard and most others are seldom total or final, and corrective procedures change as mining conditions change.

In room-and-pillar mining, falls of roof and rib may be either planned, as in the case of retreat mining, or unplanned. Obviously, it is the unplanned failures that present the greatest concern. The problem is to anticipate the failure and deal with it in such a way that a margin of safety can be maintained. Limited data exist with respect to the frequency of the unplanned failure. In a study conducted by Peters and Wiehagen, 88 of 143 miners interviewed reported that they had either been injured or startled by a rockfall at least once during the past year (1).[4] This suggests that unplanned rock falls are a relatively common event.

[1]Mining engineer.

[2]Supervisory industrial engineer.

[3]Research sociologist. Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

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

In a recent review of Mine Safety and Health Administration (MSHA) accident and fatality reports, it was noted that groundfall accidents may have been prevented in many of the cases had the worker been able to detect the presence of potentially hazardous features and properly assessed the risk. For example, the following conclusions were filed by MSHA inspectors following two investigations: "the accident occurred when a piece of undetected roof (horseback formation) fell from between the roof bolts causing fatal injuries to the victim" and "the contributing factor to the accident and resultant fatality was the presence of an undetected kettlebottom near the face of no. 5 entry".

Of course, it is impossible to ascertain the perceptual capabilities of the persons involved with any degree of accuracy. The visual information available to the miners at the moment of the accident may have been occluded (rock dust, bad viewing angle, inadequate lighting, etc.), or perhaps the persons did indeed recognize the hazards but failed to assess the degree of danger. This suggests, then, that the opportunity may exist for improvement in the perceptual skills of the persons involved in recognizing and responding to hazardous roof conditions.

This paper is concerned with the visual skills of underground miners in the recognition of roof, rib and floor hazards and the utilization of stereoscopic slides for improving their ability to perceive these hazards. Hazardous ground conditions, in most cases, have cues or warning signs associated with them and the safety of the worker is highly dependent on his or her ability to observe these warning signals. Understandably, miners possess varying degrees of hazard recognition skills that have been acquired throughout their working years from both job experiences and training. Of course, new miners must rely almost entirely on training, at least initially, for the acquisition of adequate hazard recognition skills needed to safely perform work duties underground. It is important for the health and safety of the miner that hazard recognition skills be taught and reinforced on a regular basis. The manner in which this can be accomplished more effectively is the subject of this paper.

GROUND-CONTROL PERFORMANCE DOMAINS

In any problem solving situation where information must be gathered and action taken, the persons involved must coordinate and use a number of learned capabilities. Gagne and Briggs have summarized these capabilities into five major areas: (1) the gathering and recall of information, (2) the use of intellectual skills, (3) the development of cognitive strategies, (4) attitudes, and (5) the possession of requisite motor skills (2). The existence and correct use of these capabilities as they relate to roof and rib control would lead to the anticipation and correction or avoidance of the impending fall; the absence or incorrect use of these capabilities would result in human error, and as a matter of chance, perhaps result in a serious lost-time accident or fatal injury. The following account of a fatal accident will be used to illustrate this concept.

On April 2, 1985, a miner helper was killed by a fall of roof while installing temporary support for setting line brattice inby permanent support. The accident involved a 7-ft by 7-ft by 7-in-thick slab of the immediate roof shale. Investigators reported that although the fallen slab was not a true kettlebottom, it was similar in shape. It was nearly circular in plan view and was bounded on one edge by a slickensided surface. One side of the slab coincided with a portion of a flattened, carbonized fossil tree trunk that was oriented parallel to the shale bedding and was approximately 20 in wide. It appeared that the rock separated along the outby (slickensided) edge, along the plant fossil, and along a shale lamina. The rock then sheared along the inby edge near the rib. The investigators concluded that the victim, who had 36 yr of mining experience, failed to detect the loose rock and placed himself in an unsafe position while advancing the line brattice.

The victim, for whatever reason, did not bring an adequate combination of capabilities to that particular situation to allow him to *perceive* a warning, *recognize* the warning, *assess* the risk adequately, and *respond* in an appropriate manner. Consider how a better mastery of the skills patterned from Gagne's performance domains might have prevented the accident. Obviously, the following discussion is based on speculation. None of the authors was present at the scene of the fatality, and the investigators did not couch their report in terms of the quality of performance across skill categories. In other words, it is not known, empirically, at what stage in the process the miner's failure actually occurred.

First, a worker obtains certain *information* from the work activity. This information may be gotten by associating the present circumstances with prior learned information about such circumstances, or it may be derived from the task itself, in the form of visual or audible stimuli. In the case being discussed, kettlebottoms, while not common, had been encountered on the section. The section was also known to contain slickensided roof. Therefore, the victim should have associated that knowledge with the fact that he was preparing to move past permanent support. It is not known whether the slip was clearly visible, but in most cases there is some "potting" along a slickenside (3). It is likely that a kettlebottomlike slab would provide some visual stimuli to the attuned observer.

Second, a worker must use his or her *intellectual skills* in the discrimination of relevant cues inherent in the situation and in the recall and identification of an appropriate ordering of rules for dealing with those cues. The fallen slab was bounded on one side by a fossilized tree trunk, which was probably visible, and on another side by a slickenside. The visual stimuli should have warned the victim that he was encountering a section of nonuniform or discontinuous top. In addition, it is customary to sound the roof before entering a place beyond the last row of permanent support. Sounding the roof may well have provided an audible indication that the rock was loose. Assuming that a warning was perceived, the next step would have been to recognize it for what it was: an indication that the victim should not go past the permanent supports because roof conditions had changed.

Third, a worker must develop *cognitive strategies* that allow him or her to evaluate the consequences of alternative actions. There are two types of actions the victim might have taken if he had recognized the warning: (1) effective direct action or (2) secondary action. One direct action could have been to place the head of the continuous miner against the roof for extra support, as mandated by company policy. This was not done. A secondary action would have entailed issuing an appropriate warning to some other worker, such as the miner operator. This was not done, presumably because the miner helper did not recognize the warning. In sum, the victim took no action, although there were almost certainly some cues that might have served as an indication that potentially hazardous conditions had developed.

Fourth, a worker possesses *attitudes* that are brought into play in choosing to act on a specific alternative. In this incident, it is not known whether the victim examined the roof before going inby permanent support. It is known that he did not place the head of the mining machine against the top for additional protection (a safety procedure that was supported by company policy). It is also known that the victim was working further from the rib than allowed by the roof control plan at the time he was killed. It might be inferred, therefore, that the individual chose to take shortcuts, either for personal convenience or in order to finish the task more quickly.

Fifth, a worker must have, to some degree, the *motor skills* necessary to carry out a particular procedure. The miner helper obviously had the skill required to set temporary supports and hang curtain. More importantly, however, he had the skill to operate the continuous miner. Therefore, he could have taken the extra precaution of placing the machine head against the roof while he was setting the jacks. What is not revealed in the investigation is any information about the victim's physical condition. It is possible that the manner in which he was working was partially to compensate for a relative lack of mobility or agility, as he did not restrict himself to the limited workspace allowed by the roof control plan, or perhaps the task at hand could not be performed within the restricted workspace.

The victim did not, for whatever reason, exhibit mastery of the immediate task with which he was confronted, thus leading to a fatal error. The question naturally arises as to whether he could have been trained to a level of skill in all five domains that would have prevented his making the error that led to his death. Theoretically, the answer is yes. However, simply giving him more training than he had already received would not have sufficed. Gagne established conclusively that training without evaluation, or a training and evaluation program that does not cover performance across the five capability domains, tends to be inadequate. Applied to roof and rib training, a teaching and testing situation would need to allow the full exercise of intellectual skills, cognitive strategies, and attitudinal capabilities that involve hazard perception, recognition, assessment, variable response to a warning, and the consequences that these responses produce (4).

But how can a teaching and evaluation program be carried out - especially one that deals with situations as fluid as the underground environment? Cole, using Gagne's paradigm, began by defining people's task performance in terms of verbs that describe the necessary capabilities and the conditions under which the performance is to occur (5). These capability verbs show what it is the trainee must do in order to perform a particular task to a criterion of mastery. A listing of these verbs as they apply to desired performance will clearly outline the instruction needed to teach the targeted skill and will also reveal the means for evaluating the student's competence. In terms of a problem scenario based on the fatal incident discussed, the trainee would exhibit mastery when he or she could, among other things: (1) *perceive* a warning embodied in the potting along a slickensided slip, (2) *recognize* the warning by defining the condition as a slickenside, (3) *assess* adequately the risk of venturing past permanent support at that point, and (4) *demonstrate* an appropriate response in that situation.

The appeal of designing a training program using a paradigm adapted from Gagne is that there is no distinction made between teaching and testing. They are one and the same. Only the emphasis changes: if the trainer is interested primarily in enhancing trainee skill in a given domain, the task is instruction. If the instructor is concerned with assessing trainee level of proficiency, the task is evaluation. Research has shown that administration of tasks that give the instructor information about the present proficiency of students, while at the same time providing them an opportunity to practice (and get better at) the capabilities demanded by the task, is a valid approach in several technical fields. Recent studies supported by the Bureau have shown that it is an equally valid approach in mine training (6). However, providing this instruction systematically in a fluid, on-the-job training environment is not always practical, nor is it very efficient, particularly for a large class of trainees or for the small mine operator. In addition, teaching and testing on the job carries certain risks, as the penalty for errors may be extremely high. The problem, then, becomes one of how to transfer real-world conditions to the classroom and selecting an aspect of those conditions on which to focus.

TEACHING AND ASSESSING HAZARD PERCEPTION IN THE CLASSROOM

In a South African study of 405 fatal gold mining accidents, Lawrence noted that 75 pct of the fatalities were the result of rockfalls (7). In addition, the single biggest category of error (36 pct) involved failures to perceive warnings. Although it is not known precisely what percent of error involves failures to perceive warnings, the same sort of situation seems to prevail in underground coal mining in this country. During the 5-yr period 1980-84, for instance, 16,352 groundfall accidents were reported to MSHA. These accidents resulted in 181 fatalities and caused 5,323 nonfatal injuries (8). It would seem, therefore, that a fruitful area for systematic training and assessment in the classroom would be the perception and recognition of roof and rib hazards.

The expected benefit from such an effort would be fewer unplanned falls of roof and rib, resulting in fewer production delays and, more importantly, a base reduction of injury risk. Ideally, there would be a more efficient transfer of learned skills and knowledge from the classroom to the mine if training were to be focused on the development and evaluation of specific skills (perception, recognition, and action) composing competence in the performance of the underground task. Since the miner must constantly divide his or her time between the task at hand and environmental conditions affecting both personal safety and the safety of the crew, considerations of task loading are important. Teaching miners to efficiently "read" the underground environment, including the use of cognitive strategies to direct the decision for action, then becomes an important training objective.

Most safety training programs teaching hazard recognition are based on the ideal of enhancing miner knowledge of underground hazards, with little if any emphasis on skill evaluation. The lack of rigor in pursuing a competency-based program aimed at perception and recognition skills has resulted in a training system overly dependent on real-world conditions to both teach and assess the ability of miners to deal with roof and rib problems. The only viable dependent measure in this case would be the use of injury data and investigations of fatalities, as noted in the introduction to this paper. There are certain limitations to the use of these kinds of data as an index of training effect. For instance, injuries are fairly rare events for any particular mine site; the average frequency rate for a lost-time injury in an underground coal mine is 0.06. Obviously, an attempt to show the effect of a training treatment on these small numbers would be suspect and would be very difficult to prove.

Ideally, the best way to assess the effect of a training treatment would be to sample a person's performance in the work setting. In the case of ground hazards, however, assessing an individual's perceptual, recognition, and decisionmaking skills would be difficult at best. The training and evaluation task would be totally dependent upon the existence of an adequate and representative sample of roof and rib hazards. Observer error would be a major obstacle as the behavioral implication of perceptual and recognition skill domains are not always obvious.

What is needed in the training and assessment of ground-hazard perception and recognition, then, is a training device that will simulate, to a high degree of fidelity, ground conditions that the trainees are intended to perceive and recognize. The need for classroom simulations of real conditions has long been recognized. Gibson for instance, suggested that in industrial training there should be devices that would simulate particular dangers while allowing subjects to act safely or unsafely (9). The problem with simulations, however, is that they often have an artificiality that is difficult to surmount. Confounding the simulation problem is the enormously complex mine environment where the visual cues, in many cases, are subtle and not readily apparent to the observer. These cues may be inhibited because of severe angles of sight (common in low-coal mine roof), abundance of rock dust, insufficient lighting, etc.

One attempt to simulate ground hazards in mining was carried out by Blignaut, who had subjects perform motor tasks while simultaneously looking for "loose rock" in a stope simulator (10). Although Blignaut reported that the simulator was viewed as realistic by the participants, such a device would be relatively difficult and expensive to build with any degree of fidelity. A second attempt to simulate ground hazards, also by Blignaut in 1979, appears to offer more promise to mine safety trainers.

STEREOSCOPIC SLIDES

Blignaut attempted to simulate ground hazards using stereoscopic slides for training underground miners. The results of his study, involving South African gold miners, suggest that the ability of underground miners to discriminate between dangerous and safe rock conditions can be significantly improved by exposing them to stereoscopic (3-D) slides of groundfall hazards. Although Blignaut's results were encouraging, they failed to provide a set of guidelines for the use of 3-D training aids to teach recognition skills and measure perceptual competence. Therefore, the Bureau undertook a pilot study to determine the efficacy of using stereoscopic slides for ground-hazard awareness training.

The first step was to generate a set of (3-D) slides of hazardous roof and rib conditions typically found in mines throughout the major coal producing areas of the eastern United States. For example, 3-D slides were taken of specific geologic features, such as joints, bedding planes, and kettlebottoms; inadequate support conditions, such as spalling ribs, loose or hanging bolts, and incorrect bolting patterns; and loose rock occurrences such as overhangs.

These 3-D slides were then used in an experiment involving a group of 20 experienced miners (minimum 1 yr at the face) and 20 persons with very limited or no underground experience. The slides with embedded hazards were judged to be rather common and somewhat obvious hazards by roof and rib experts. The subjects were presented with 15 slides of varying roof and rib conditions and asked to describe what, if anything, in the slide appeared hazardous. Half of each of these two groups of miners were shown the areas of roof and rib using 3-D slides, and the other half were shown the same areas using identical, standard two-dimensional (2-D) slides. A 2 by 2 analysis of variance was applied to determine the significance of the main effects of level of experience and mode of stimulus presentation. Both main effects were found to be highly significant ($p < 0.01$), indicating that (1) in comparison to the group of persons with very limited or no underground experience, the proportion of correct responses was significantly higher among those with at least 1 yr of experience working at the face, and, (2) in comparison to the group who viewed the 2-D slides, the proportion of correct responses was significantly higher among those who viewed the 3-D slides.

The first of these two findings suggests that significant differences exist between the ability of new versus experienced miners to correctly identify groundfall hazards. However, on the average, even the experienced miners failed to correctly identify 2.5 out of 15 hazards. These data suggest that better training in recognizing groundfall hazards could be beneficial for all miners, and that it would have the greatest impact on miners who have little or no experience working at the face.

The second finding strongly suggests that 3-D slides are more effective than 2-D slides for the purposes of illustrating groundfall hazards. Combined, the findings suggest that 3-D slides are a more effective tool for illustrating groundfall hazards than 2-D representations and, therefore, offer promise for enhancing the perceptual skills of the miner.

PHOTOGRAPHIC EQUIPMENT

Authentic commercially available stereoscopic-slide cameras are 35-mm slidefilm cameras (print film cannot be used in these cameras to make stereoprints) that have dual, matched objective lenses with mechanically coupled iris diaphragms. The distance between the lenses is fixed at 2.75 in. They have a normal range of aperture settings, shutter speeds, hot-shoe adapters for flash cords, and focus adjustments. The slidefilm is commercially developed and mounted by an experienced person who is familiar with left and right balance of stereo pairs.

Stereoscopic slides can either be projected on a screen or viewed through hand-held devices. The equipment required to project 3-D slides on a screen includes a 3-D slide projector and a lenticular beaded screen. The projected image is not as clear as that observed in a hand-held 3-D viewer. Polarized glasses must be worn to see projected slides in 3-D, but the glasses are not required with a hand-held viewer.

Because of decreasing demand as well as limited utility, the manufacture of 3-D slide cameras terminated over 30 yr ago. However, the cameras may still be purchased from used-equipment and secondhand photographic supply stores; some have even become collector's items among camera enthusiasts. In addition to uncertain availability, the original 3-D cameras have several operational limitations. These include built-in lenses that cannot be interchanged, antiquated manual controls, and difficult focusing adjustments (particularly in the minimally lighted underground environment).

To overcome the limitations of 3-D cameras noted above, the Bureau designed and fabricated a stereoscopic 35-mm camera slide bar for producing 3-D slides using just one 35-mm, single lens reflex camera. This apparatus can be used to take pairs of individual slide chips (left slide and right slide) from two preset locations that correspond exactly to the interocular distance (2.75 in) used on the dual lens stereocameras.

The unit basically consists of three horizontal bars situated one above the other (fig. 1). The lower bar is used for mounting on a tripod and for holding a simple line level. The middle bar holds the 35-mm camera, which is attached to a track-mounted sliding plate, and the upper bar supports the strobe light that is secured at a location central to each camera position.

The 35-mm slide chips can be mounted individually in slide holders, in the conventional manner, or combined in specially made stereomounts for viewing in the hand-held viewer. The matched slide pairs can be projected on a lenticular screen, from any convenient distance, using two conventional slide projectors positioned vertically (fig. 2). The lenses used on the projectors should be identical and polarizing filters are required for each lens. If hand-held viewers are used, then the 35-mm film chip pairs are mounted in aluminum stereoslide holders and cardboard stereomounts. Both of these items are available in photographic supply stores. The mounting procedure is quite simple and can be accomplished with very few problems by a novice. Alignment of the film chips in the mounts is critical and must be done carefully. It will be obvious when the proper stereo balance of the slide chips is achieved because the image in the viewer will have depth and be clear throughout.

The equipment and procedures for generating stereoscopic slides are quite basic and involves just a minimum investment of resources. Fabrication of the Bureau-developed slide bar is relatively simple and inexpensive (detailed design drawings can be obtained from the author). The slide bar, unique in its own design, has several operating features that insure quality slides that have proper lighting and adequate stereo-balance. These include a central, fixed flash or strobe light location, a track-mounted camera slide plate, use of a single 35-mm camera, and a leveling device.

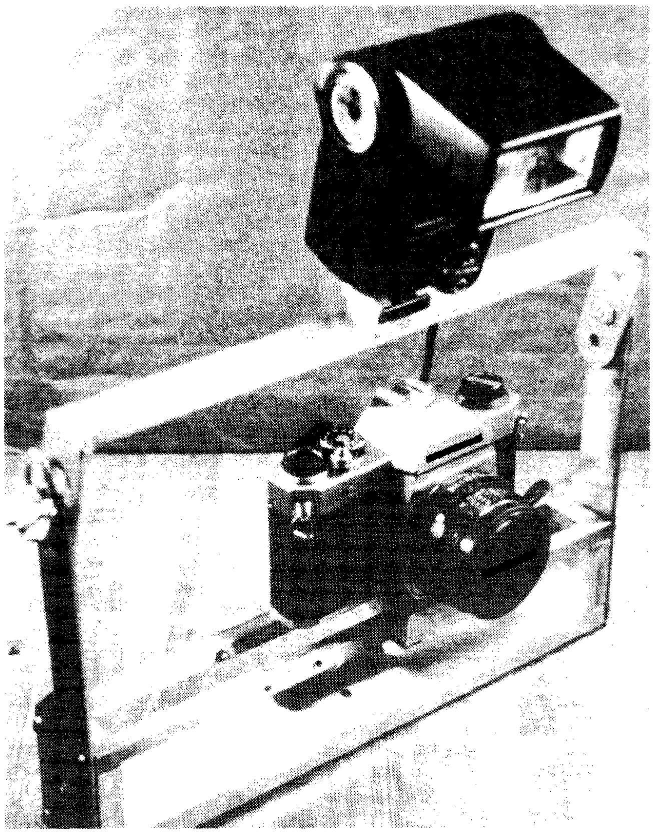

FIGURE 1.—Slide bar for use in generating stereoscopic slides with conventional 35-mm camera.

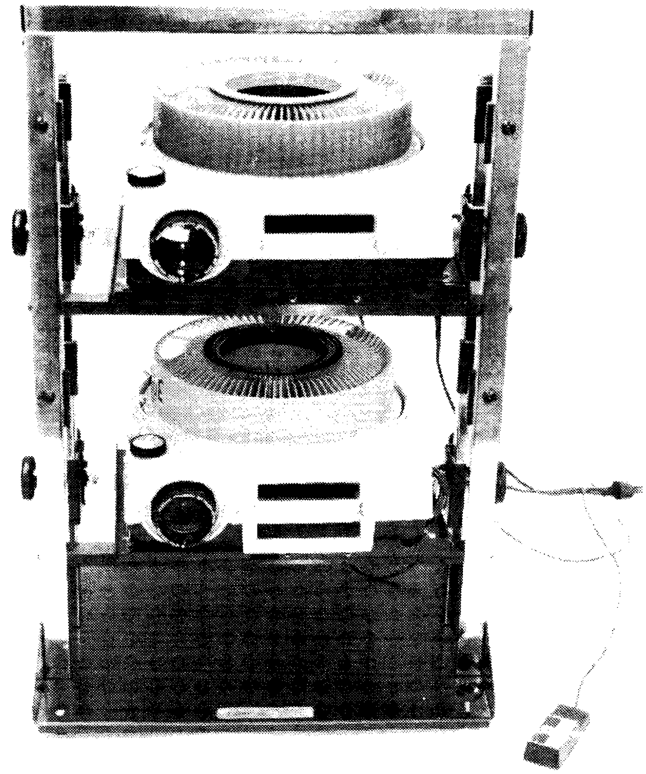

FIGURE 2.—Two slide projectors positioned vertically on two-tier stand.

USING STEREOSCOPIC SLIDES IN THE CLASSROOM

In order to create optimum interest among trainees and to motivate them for maximum involvement in the learning process, mine trainers may prefer to generate customized sets of 3-D slides of the groundfall hazards found throughout their own mines. The customized slides, perhaps even depicting hazards that exist in the current working sections, could be assembled and updated to meet training objectives by in-house personnel.

A typical classroom training session could begin with each trainee having a hand-held viewer and the same set of slides depicting the ground hazards selected for study. In a group discussion format, everyone would observe the same slide and talk about the important features. For example, a kettlebottom is defined as a smooth, rounded, sometimes oval piece of rock, cylindrical in shape, the surface of which usually has a striated or slickensided appearance. From this definition, the cues that the miner would be taught to look for in recognizing this potentially hazardous feature are as follows: rounded piece of rock within mine roof, different in nature from surrounding roof material, and shining or glossy edge. Since kettlebottoms can range from a few inches in diameter to more than 4 ft, it is important for the worker to be cognizant of the entire viewing area of mine roof in order to, perhaps, notice one small, isolated kettlebottom. To address this latter concern, expanded views, beyond the individual feature, may need to be developed (not necessarily 3-D) and used to supplement the training lesson. This would likely involve different angles, different degrees of lighting, and multiple distances from the target area.

In addition to being used for training, 3-D slides could be utilized for screening miners, before or after instruction, to determine their level of competence in recognizing roof and rib hazards. By asking miners to identify the presence of hazards in a series of 3-D slides, one can determine (1) which types of hazards are not recognized by a significant number of people, and (2) which miners seem to be particularly deficient in their ability to recognize groundfall hazards. Given this baseline information, the trainer can better determine which types of groundfall hazards need to be emphasized in the present or future training, and which miners need additional instruction to become proficient at recognizing the hazards. Because of the high fidelity of 3-D slides and the realism thus portrayed, there can be no confusion in the process of accurately identifying hazards.

DISCUSSION

The fact that mine workers can improve their ground-hazard awareness skills for recognizing potentially dangerous conditions was demonstrated by Blignaut using 3-D slides as an experimental tool. This development, combined with the experimental results in the Bureau's field evaluation studies, indicates that 3-D slides have the potential to be a very effective training aid. It is unlikely that conventional means for representing roof and rib hazards would provide similar results. Drawings, photographs, and standard slides provide visual cues in two dimensions only; consequently, realism is lost. The only other alternative for transferring basic concepts of ground control to the miner is to go to the underground workplace and point out each detail as it is encountered. Of course, the dilemma here is that many hazards will never get taught simply because they do not exist in a particular mine or, if they do exist, their nature will be different from that under study. For example, consider the condition known as cutter roof. Cutter roof will initially appear as a short separation in the mine roof running in the direction of the opening along the rib line and will eventually develop into much longer separations that run on both sides of the entry. Ultimately, an entire area affected by cutter roof could fail in shear and fall in at the roof bolt horizon level. Obviously, all stages of this hazard do not exist in any given mine at one particular time.

The miner who is competent in all aspects of ground control is one who consistently demonstrates knowledge, procedures, and skill in the perception, recognition, and correction of every potentially hazardous condition. Using the preceding example, the miner must be able to observe the preliminary indicators of cutter roof as well as any of the intermediate signs, and then respond appropriately. This pattern of performance corresponds with that developed by Gagne and, in effect, suggests the structure necessary for completely training the miner.

Training for competency in this expanded mode has further payoffs. The obvious benefit of improved safety in the mine is amended by a more accurate account of the allocation of training resources. Management can see where the emphasis is being placed and what the results are.

The use of 3-D slides for conducting ground-hazard training in the classroom presents an ideal learning situation. No other inexpensive and readily available classroom training aids that have the same fidelity as 3-D slides could be utilized for this purpose. The slides ostensibly take the miner into the mine without leaving the classroom. This feature makes them valuable as a training aid because training effectiveness and training transfer depend on materials that physically simulate the real-world environment.

Once an acceptable level of proficiency is established, poor recognition skills can be ruled out as a reason for continuing groundfall hazard problems in the working area. Other causes would then need to be considered. For example, miners may not know when to correct groundfall hazards or may be insufficiently motivated to correct them. Strategies for dealing with these problems include training designed to ensure that miners know when potential hazards become actual problems, training designed to emphasize how dangerous it is if they fail to correct such hazards, and establishing a system of rewards to motivate miners to take the time to look for groundfall hazards and correct them.

SUMMARY

Evidence exists that miners often fail to recognize areas of hazardous roof and rib. Mine safety and training personnel, miners, and ground-control specialists who have examined 3-D slides of groundfall hazards report that the slides could significantly improve miner ability to identify hazardous roof and rib. There are a number of advantages to using 3-D slides instead of conventional slides or other two-dimensional techniques for illustrating groundfall hazards to miners. Perhaps the most important advantage is that 3-D slides provide a more realistic and accurate representation of roof and rib hazards.

From a motivational standpoint, another advantage to stereoscopic slides is that, because of their novelty, they are intrinsically interesting to most viewers. Miners are more enthusiastic about training that involves 3-D slides and seem to enjoy looking at this type of slide. Based on the responses of various miners and mine trainers, it appears that 3-D slides would be very well received as a training aid throughout the industry. Also, the equipment needed to generate and use stereoscopic slides for training is relatively inexpensive and easy to obtain and operate.

In conclusion, the information the Bureau has gathered on the feasibility and effectiveness of using 3-D slides as a training aid strongly suggests that it is both feasible and advisable for the coal mining industry to use stereoscopic slides of hazardous roof and rib conditions as an aid to improving miner ability to recognize potential hazards.

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HUMAN FACTORS CONTRIBUTING TO GROUNDFALL ACCIDENTS IN UNDERGROUND COAL MINES: WORKERS' VIEWS

By Robert H. Peters[1] and William J. Wiehagen[2]

ABSTRACT

Groundfall accidents are the most common cause of accidental death among underground coal miners, and in many mines, they are a significant part of the total cost of operating the mine. This paper presents results of a Bureau of Mines study on barriers that may prevent miners from correcting and avoiding groundfall hazards. Such barriers stem from four basic types of problems: (1) inability to recognize groundfall hazards, (2) inability to correct groundfall hazards, (3) lack of motivation to search for groundfall hazards, and (4) lack of motivation to correct groundfall hazards.

Interviews were conducted with 143 miners and 9 Mine Safety and Health Administration (MSHA) coal mine roof and rib inspectors to determine the perceived importance of these four categories of barriers, and what should be done to overcome them. The issues covered in these interviews were (1) why miners sometimes fail to do anything about potential roof hazards, (2) walking beneath unsupported roof, and (3) what should be done to help miners to avoid rock fall injuries. Participants' beliefs about these issues were determined by asking them to respond to a series of open-ended and forced-choice questions. The frequencies with which response categories were chosen to reply to each question are presented. It is concluded that those who work underground consider all four types of barriers to be important contributors to groundfall accidents.

INTRODUCTION

In many underground coal mines, the economic costs associated with falls of roof and rib are a substantial proportion of the total costs of operating the mine. During the 1982-86 5-yr period, 14,863 groundfall accidents were reported to the Mine Safety and Health Administration (MSHA).

These accidents often require that labor, supplies, and equipment be diverted from coal production and used for cleanup, recovery and repair of mine equipment, and resupport of the mine roof. The costs of these activities are quite substantial. But of even greater significance are the intangible losses and the emotional anguish suffered by the families of miners who have been killed or seriously disabled by groundfalls. During the 1982-86 period, groundfall accidents claimed the lives of 154 coal miners and caused 4,249 nonfatal injuries. According to an accident cost model, the direct cost of these fatalities and injuries alone exceeds $200 million.[3] (Clearly, there is a great need to further reduce the number of miners being injured and killed by groundfall accidents.)

The Bureau performed the research described in this report in order to (1) better define the types of barriers preventing miners from correcting or avoiding groundfall hazards, (2) provide direction for future research, and (3) identify promising approaches for preventing this type of accident. Data were collected using structured interview guides. Interviews were conducted with various personnel from three underground coal companies (nine sites) and with MSHA coal mine roof and rib inspectors.

[1]Research psychologist.

[2]Supervisory industrial engineer. Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

[3]DiCanio, D. G., A. H. Nakata, D. Colvert, and E. G. LaVeque. Accident Cost Indicator Model to Estimate Costs to Industry and Society From Work-Related Injuries and Deaths in Underground Coal Mining. Volume III. Supporting Data (contract J0255031, FMC Corp.). BuMines OFR 39(3)-77, 1976, 104 pp.; NTIS PB 264 440.

BARRIERS TO MINER PREVENTION OF GROUNDFALL ACCIDENTS

Geological factors relating to the inherent stability of the roof and rib influence the likelihood of a groundfall accident. Although geological history cannot be changed, there are several other factors that influence the probability of groundfall accidents over which people potentially have some control. This study focuses primarily on assessing the things miners can potentially do to avoid groundfall accidents, and on gaining a better understanding of the types of barriers that prevent them from performing these activities.

Figure 1 highlights a conceptual framework for addressing these barriers. The model assumes that in order for miners to do an effective job of preventing groundfall injuries, they must not only recognize the existence of the hazard but also must be willing and able to take corrective action. Barriers can be differentiated on the basis of whether they occur at the stage of hazard recognition or hazard correction, and on the basis of whether they are due to miner lack of ability or lack of motivation.[4] Data were collected to determine whether the people who work underground consider the barriers identified in figure 1 to be important contributors to groundfall accidents.

Source of barrier	Stage of barrier's occurrence: Recognition	Correction
Ability	Inability to recognize groundfall hazards	Inability to correct groundfall hazards
Motivation	Lack of motivation to search for groundfall hazards	Lack of motivation to correct groundfall hazards

FIGURE 1.—Barriers to miner prevention of groundfall accidents.

METHODS OF DATA COLLECTION

Miners and MSHA inspectors were asked to respond to a variety of questions about the causes and prevention of groundfall accidents in one-on-one interviews. Interviewers asked questions concerning the following issues: (1) Recent experiences with roof falls, (2) why miners sometimes fail to do anything about potential roof hazards, (3) walking beneath unsupported roof, (4) the degree to which various changes would help miners to avoid rock fall injuries. Participants were asked to respond to both open-ended and forced-choice questions.

Data were collected from February 1984 to April 1985. A total of 143 employees from three underground coal mining companies located at nine sites in Pennsylvania, Virginia, and Kentucky participated in the study. All mines in this study were using the room-and-pillar method of extraction and continuous mining machinery. Table 1 breaks down the total sample of mine employees by job title. The average length of time spent working as an underground coal miner was 10.5 yr. Of the 143 employees in the sample, 85 pct had some experience working as a bolter or bolter helper. All 143 employees work underground on a daily basis. Data were also collected from nine MSHA coal mine roof and rib inspectors using the instruments and methods previously described.

TABLE 1. - Breakdown of mine employees interviewed, by job title

Job title	Number
Belt worker	4
Bridge worker	2
Continuous miner operator	16
Continuous miner operator helper	10
General inside labor	10
Mechanic	11
Roof bolter operator	27
Roof bolter helper	10
Scoop operator	2
Section supervisor	14
Shuttle car operator	25
Supply worker	2
Timber worker	5
Utility worker	5
Total	143

[4]For a more detailed discussion of this model see: Peters, R. H., and W. J. Wiehagen. Human Factors Contributing to Groundfall Accidents in Underground Coal Mines: Workers' Views. BuMines IC 9127, 1987, 24 pp.

PRESENTATION OF FINDINGS

This section presents participants' responses to interview questions concerning nonresponse to possible roof hazards, walking beneath unsupported roof, and the effect of various changes on preventing groundfall accidents. Simple frequencies of the response categories miners chose to answer each forced-choice question in the interview are presented. Summaries of responses to several open-ended questions are also presented.

NONRESPONSE TO POSSIBLE ROOF HAZARDS

Each participant was initially asked to respond to an open-ended question on this topic. This question was followed by eight forced-choice questions.

Open-Ended Questions

Participants were asked for their opinions about why miners sometimes neglect correcting hazardous roof conditions. This question was asked as follows:

> At one time or another, most miners have seen areas of the roof that look like they may not be entirely safe, but for some reason, do not do anything about it. What are the major reasons why miners sometimes fail to do anything about potential roof hazards?

The miners' replies and (in parentheses) number of respondents were—

In a hurry (22)
Laziness (15)
The area is traveled infrequently (11)
Too busy doing other work (10)
Don't want to delay production (10)
Careless or don't care (8)
Don't believe it's hazardous (7)
It's not their job (7)
Complacency (6)
I know it's there so I'll just stay away from it (4)
Tools or supplies not readily available (4)
Afraid of getting hurt (4)
Put off doing it but forget (3)
Lack of knowledge or experience (2)
Taking shortcuts (2)
Not important; it's just "extra work" (2)

Inspectors gave several different types of responses to this question. The most common response was that miners do not think it is worth the time and effort required; i.e., they are insufficiently motivated to perform this type of activity.

Another reason frequently mentioned by mine inspectors was that miners do not realize how dangerous the hazard really is. Several inspectors also said that because nothing usually happens to miners who occasionally decide to risk working beneath hazardous roof, many tend to become complacent. Apparently, the failure to experience negative consequences for deviating from a safe work practice may promote continued deviation. Other factors believed by mine inspectors to contribute to miner failure to correct roof hazards were (1) miner inattentiveness caused by preoccupation with off-the-job problems (e.g., family, medical) and (2) the temptation to let the next shift deal with the hazards when it is close to quitting time.

Forced-Choice Questions

Miners were asked to indicate the extent to which they agreed or disagreed that each of a list of reasons explains why miners might sometimes decide not to do anything about potentially hazardous roof conditions. The reasons were --

1. They do not have the tools or materials with them that are needed to correct the roof problem.
2. They think it is someone else's responsibility to take care of roof problems.
3. They do not want to risk getting hurt while fixing the roof.
4. They dislike doing the type of work necessary to correct the roof problem.
5. They believe that their supervisor thinks that taking care of roof problems is unimportant.
6. They do not know how to correct roof problems.
7. They do not realize how dangerous roof problems really are.
8. They do not take enough time to look for roof problems.

A six-point rating scale ranging from strongly agree to strongly disagree was used to respond to each statement. The rating scale contained the following options:

Strongly agree
Agree
Slightly agree
Slightly disagree
Disagree
Strongly disagree

The number of miners who chose each point on the rating scale to respond to each of the eight questions in this section is presented in table 2. The percentage of miners in each subgrouping who chose slightly agree, agree, or strongly agree to answer the question are summed to allow one to

TABLE 2. - Rank ordering of reasons for neglect of roof fall hazards, according to percentage of persons expressing agreement

	Total agree responses	Strongly agree	Agree	Slightly agree	Slightly disagree	Disagree	Strongly agree
A-8. They do not take enough time to look for roof problems.	80.7	11.4	55.0	14.3	5.0	14.3	0.0
A-7. They do not realize how dangerous roof problems really are.	68.4	13.7	43.2	11.5	2.9	20.9	7.9
A-4. They dislike doing the type of work necessary to correct the problem.	57.7	8.1	31.1	18.5	5.2	33.3	3.7
A-2. They feel it is someone else's responsibility.	51.5	9.2	32.4	9.9	10.6	31.7	6.3
A-1. They do not have the tools or materials to correct the problem.	51.0	7.1	32.6	11.3	7.8	32.6	8.5
A-3. They do not want to risk getting hurt.	47.9	5.0	25.0	17.9	6.4	40.0	5.7
A-6. They do not know how to correct the roof problem.	36.5	2.9	20.7	12.9	5.7	45.7	12.1
A-5. They believe that their section supervisor thinks that taking care of roof problems is unimportant.	11.3	0.7	7.8	2.8	2.8	56.7	29.1

quickly understand the general results of the data without having to perform additional calculations.

With the exception of statement A.5, a significant number of miners agreed that each of the factors listed in this section are important deterrents to the prevention of groundfall accidents. This suggests that further attention should be given to devising better ways to lessen the influence of these seven barriers.

WALKING BENEATH UNSUPPORTED ROOF

The victims of roof falls are often found in areas of unsupported roof. MSHA fatality reports indicate that more than half of the 97 deaths due to groundfalls in coal mines during 1979 and 1980 occurred in areas of unsupported roof. This series of questions were directed toward better defining the reasons why miners fail to avoid unsupported roof, how many miners go beneath unsupported roof, and how often.

Reasons for Going Beneath Unsupported Roof

MSHA roof and rib inspectors were asked what motivates miners to illegally go beneath unsupported roof (the only legally permissible reason for going beneath unsupported roof is to set temporary supports before installing permanent supports). The most common reply to this question was that miners do it to save time and/or effort; i.e., they want to take a shortcut.

Inspectors mentioned several factors that sometimes contribute to miner willingness to risk working beneath unsupported roof. Among them are the following:

They are in a hurry to get more coal out, especially if they think they are behind.

They want to cut down the walking distance to a place they need to go.

They think that the unsupported roof looks good.

They do it inadvertently.

They have done it before without getting hurt.

They are unwilling to set temporary supports.

In order to finish loading a shuttle car, continuous miner operators might go a little beyond the edge of properly supported roof.

Proportion of Miners Going Beneath Unsupported Roof

In order to roughly estimate the proportion of miners who go beneath unsupported roof, miners were asked, "During a typical month, what percent of miners who work at the face go beneath unsupported roof for reasons other than to set temporary supports?" Miners' responses to this question are given in table 3. The median of the estimates for the percentage of miners who go beneath unsupported roof during a typical month was 10 pct. This means that half of the estimates were greater than 10 pct and half the estimates were less than 10 pct. This suggests that the percent of miners going beneath unsupported roof is relatively low.

In order to estimate the frequency with which miners go beneath unsupported roof, miners were asked, "Considering a typical crew of miners who work at the face, how often does someone go beneath unsupported roof for reasons other than to set temporary supports?" Miners' responses to this question are listed in table 4. Forty-four percent indicated that they believed that someone goes beneath unsupported roof at least once per shift!

Twenty-five percent indicated that they believed that someone goes beneath unsupported roof at least once per week but not as often as once per shift.

TABLE 3. - Estimates of the percentage of miners who go beneath unsupported roof during a typical month

Participant estimates, pct	Frequency of estimates	Frequency, pct
0	34	27.2
1	9	7.2
2	8	6.4
5	9	7.2
9	1	.8
10	21	16.8
15	2	1.6
20	7	5.6
25	7	5.6
30	4	3.2
35	2	1.6
50	13	10.4
60	1	.8
75	2	1.6
80	2	1.6
90	2	1.6
100	1	.8
Total	125	100.0

TABLE 4. - Estimates of the frequency with which someone in a typical crew of miners goes beneath unsupported roof

Participant estimates	Frequency of estimates	Frequency, pct
At least once per shift	48	43.6
At least once per week but less often than once every shift	28	25.4
At least once per month but less often than once every week	16	14.6
Less than once per month	18	16.4
Total	110	100.0

These estimates suggest that going beneath unsupported roof is not an uncommon event in a typical mining crew, and, that more attention should be given to preventing miners from engaging in this practice. In conjunction with the data from table 3, these estimates suggest that (1) few miners are going beneath unsupported roof, but, (2) those who are going beneath unsupported roof are doing it rather often.

EFFECT OF VARIOUS CHANGES ON PREVENTING GROUNDFALL ACCIDENTS

Each participant was initially asked to respond to an open-ended question on this topic. This question was followed by nine forced-choice questions.

Open-Ended Questions

Miners were asked for their opinions about what should be done to reduce the number of rock fall accidents in the coal industry.

Their replies and (in parentheses) number of respondents were—

- Better training (19)
- Inspect the roof more often (14)
- Don't make entries too wide (7)
- Drill test holes more frequently and deeper (7)
- Always set temporary supports before walking beyond bolts (7)
- Put more emphasis on the dangerousness of groundfall accidents (7)
- Follow the roof control plan/bolting pattern more closely (6)

Use more of the automated temporary roof support (ATRS) type bolter (5)
Recheck existing supports more often (5)
Add more supports to bad areas (5)
Stricter supervision (4)
Use more bolts (4)
Use longer bolts (4)
Don't rush (4)
Put less emphasis on production (3)
Scale the roof better (2)
Check the torque on roof bolts more often (2)
Sound the roof more often (2)
More safety talks (2)

Other responses included putting canopies on roof bolters, operating equipment by remote control, offering bonuses for good roof support, installing roof supports more quickly after the area is mined, installing bolts closer to the rib, encouraging communication between miners about the existence of new roof problems, and explaining some of the theoretical principles behind roof support.

MSHA inspectors were also asked what they thought needs to be done to prevent more roof fall accidents in the coal industry. The most common response was that the use of ATRS systems on bolters should be mandatory. Such systems are expected to significantly reduce the amount of time miners spend beneath unsupported roof. Other responses include

Use remote sensing devices to check for gas at the face.

Do not assign inexperienced crews to perform retreat mining.

Encourage continuous miner operators to report roof problems to bolters.

Avoid letting sections stand idle during pillar recovery.

Ensure closer compliance with the roof control plan and other safety rules.

Improve training.

With regard to the improvement of training, inspectors recommended the following:

Supplement classroom training with structured on-the-job training in roof control and the identification of groundfall hazards.

Explain the theoretical principles of roof support to bolters in laymen's terms.

Limit the size of training classes to encourage more discussion.

Increase miner awareness of the consequences of roof falls by showing slides of roof fall accidents and relating the details of how people have been injured by them.

MSHA inspectors were asked two questions regarding the identification of groundfall hazards. They were asked to list the types of cues that can warn miners that a piece or an area of the roof is about to fall, and then to choose which of these warning signals would be most difficult for inexperienced miners to recognize as an indicator of danger. The following visual cues were mentioned:

Cracked, bent or broken support posts.

Cracks, gaps, slips, cutters, and clay veins in the roof and rib.

Heaving of the floor.

Loose rock lying on the floor.

The absence of rock dust on previously dusted surfaces.

Bent plates around bolts.

Cracked, bent, broken or squeezed cap blocks, crossbars or cribs.

Sags in the middle of the roof or crossbars.

Reduction in the clearance between tops of equipment and the roof over time.

Dust trickling down from the roof.

Water seeping out of roof bolt holes.

Kettle bottoms and other fossils.

The following auditory cues were mentioned:

Sounds associated with sounding the roof.

Noise caused by shifts in the stress distribution on various layers of rock, i.e., when the roof is working.

Cracking of wooden supports due to stress concentrations.

Pinging noises from roof bolts caused by increased roof loading.

It was noted that roof bolter operators receive several types of cues about the stability of the roof when drilling bolt holes. It was also noted that these warning signals are not universal, but may vary with the type of coal seam and geological conditions.

Responses to the question, "Which types of warning signals are more difficult for inexperienced miners to recognize than miners with several years of experience?" include the following: clay veins, cutters, sloughing of the ribs, cracking or heaving of the floor, the presence of sandstone channels, and the pinging noises produced by bolts.

Forced-Choice Questions

Miners were asked to indicate the degree to which various changes would help miners avoid rock fall injuries. The changes were

1. Better lighting.
2. Less noise.
3. Supervisor putting greater emphasis on correcting roof hazards.
4. Better training in the identification of roof hazards.
5. Better training in proper methods of supporting the roof.

6. Reprimanding or penalizing those who repeatedly go beneath unsupported roof.
7. Better scaling of the roof.
8. Adding more support to bad areas of the roof.
9. Better installation of roof bolts.

A six-point rating scale ranging from a very small degree to a very large degree was used to respond to each statement. The rating scale contained the following options:

A very small degree
A small degree
A somewhat small degree
A somewhat large degree
A large degree
A very large degree

Each of nine items were inserted into the blank as the following statement was read: To what degree would _______ help miners avoid rock fall injuries? The percent of miners who chose each point on the rating scale is presented in table 5. The first column of numbers indicates the percent of participants who chose a large degree or a very large degree to answer the question.

Table 5 rank orders the nine statements in this section in terms of the highest to lowest percent of persons who responded to the questions with large or very large. In order of descending rank, the top three items are adding more support to bad areas of the roof, better training in proper methods of supporting the roof, and better training in the identification of roof hazards. Except for better lighting, the majority of the miners indicated that all the proposed changes would help miners avoid rock fall injuries to a large or very large degree. (The corresponding percentage for better lighting was 44 pct.) These data suggest that, because of their perceived importance in reducing rock fall injuries, further consideration should be given to the possibility of implementing all of the nine changes proposed in this section.

Items B-1, B-2, B-7, B-8, and B-9 all refer to changing the physical work environment, whereas items B-3, B-4, B-5, and B-6 all refer to changes in miner training and supervision. Note that there is a tendency for the percentages of responses in the large or very large degree categories to be higher for the proposed changes in training and supervision than for the proposed changes in the physical work environment.

TABLE 5. - Rank ordering of questions about degree to which various changes would help miners to avoid rock fall injuries, according to percentage of persons who chose large or very large degree responses

Reason	Large or very large	Very small	Small	Somewhat small	Somewhat large	Large	Very large
B-8. Adding more support to bad areas of the roof.	78.9	3.0	5.3	3.8	9.0	39.8	39.1
B-5. Better training in proper methods of supporting the roof.	69.2	2.3	11.3	3.0	14.3	43.6	25.6
B-4. Better training in the identification of roof hazards.	68.4	3.0	6.0	6.8	15.8	45.1	23.3
B-6. Reprimanding or penalizing those who repeatedly go beneath unsupported roof.	60.0	10.4	14.8	5.2	9.6	28.9	31.1
B-7. Better scaling of the roof	56.7	2.2	17.2	8.2	15.7	37.3	19.4
B-3. Supervisor putting greater emphasis on correcting roof hazards	56.3	6.7	15.6	4.4	17.0	37.8	18.5
B-2. Less noise	56.0	7.5	19.4	6.0	11.2	38.1	17.9
B-9. Better installation of roof bolts	53.1	6.1	25.8	5.3	9.8	25.8	27.3
B-1. Better lighting	44.0	14.2	26.9	9.7	5.2	30.6	13.4

MINER EXPERIENCES WITH ROCK FALLS

The miners interviewed for this study were asked to provide information about their recent experiences with rock falls that is not typically collected by MSHA. Miners were asked for detailed information about either recent injuries that they had suffered as a result of a rock fall, or incidents in which they were startled because of their close proximity to large pieces of falling rock.

Miner responses indicate that unplanned rock falls in underground coal mines are a somewhat common event. Of the 143 miners interviewed for this study, 88 reported that they had either been injured or startled by a rock fall at least one time during the past year. Eighty-one percent of those who reported that they had been recently startled by large pieces of falling rock said that such an incident had happened more than once within the past year. The median of the answers was three times. Sixty-five percent of the miners who reported that they had recently suffered an injury caused by a groundfall said that they had been near the location of the rock fall for only a few minutes prior to the accident. This suggests that most rock fall accidents could be avoided if miners would always check the roof before beginning to work in a new area.

CONCLUSIONS AND RECOMMENDATIONS

The data collected for this study suggest that most people who work underground agree that the factors listed in figure 1 are significant barriers to coal miner prevention of groundfall accidents. The evidence supporting this assertion is reviewed in the following sections.

INABILITY TO RECOGNIZE GROUNDFALL HAZARDS

The reasons for an individual's inability to recognize groundfall hazards may be an attribute of the person or of the environment. Data supporting the importance of this set of factors comes from miners' responses to questions B-1, B-2, and B-4 (table 5). Forty-four percent said that better lighting would help miners avoid rock fall injuries to a large or very large degree. This implies that miners may often fail to recognize hazardous roof conditions because the illumination is not good enough to be able to detect them. Fifty-six percent said that less noise would help miners to a large or very large degree. This implies that there may often be too much noise for miners to hear sounds that could warn them that a hazardous roof condition exists. Sixty-eight percent said that better training in the identification of roof hazards would help miners to a large or very large degree. This suggests that miners sometimes fail to recognize certain types of hazardous roof conditions because they are not aware that these roof conditions should be considered hazardous.

INABILITY TO CORRECT GROUNDFALL HAZARDS

Data supporting the importance of this set of factors comes from miners responses to questions A-1 and A-6 (table 2) and B-6 (table 5). Fifty-one percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they do not have the tools or materials with them that are needed to fix the roof problem. Thirty-seven percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they do not know how to correct roof problems. This suggests that miners sometimes fail to correct certain types of hazardous roof problems because they have never learned how to correct them. Sixty-nine percent said that better training in proper methods of supporting the roof would help miners avoid rock fall injuries to a large or very large degree.

LACK OF MOTIVATION TO SEARCH FOR GROUNDFALL HAZARDS

Data supporting the importance of this set of factors comes from miner responses to questions A-8, A-7 (table 2) and B-3 (table 5). Eighty-one percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they do not take enough time to look for roof problems. One reason that miners might not take enough time to look for roof problems is that they do not realize how dangerous roof problems really are. In response to question A-7, 68.4 pct agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they do not realize how dangerous roof problems really are. Another reason that miners might not take enough time to look for roof problems is that they do not think that their supervisor wants them to devote much time to this activity. In response to question B-3, 56 pct indicated that supervisors putting greater emphasis on correcting roof hazards would help miners avoid rock fall injuries to a large or very large degree.

LACK OF MOTIVATION TO CORRECT GROUNDFALL HAZARDS

Data supporting the importance of five types of factors within this category come from miners' responses to questions A-2, A-3, A-4, and A-7 (table 2) and B-3 (table 5). Fifty-two percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they think that it is someone else's responsibility to take care of roof problems. Forty-eight percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they do not want to risk getting hurt while fixing the roof. Fifty-eight percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they dislike doing the type of work necessary to correct the roof problem. Sixty-eight percent agreed that one of the main reasons that miners sometimes neglect correcting roof hazards is because they do not realize how dangerous roof problems really are. Fifty-six percent indicated that supervisors putting greater emphasis on correcting roof hazards would help miners avoid rock fall injuries to a large or very large degree.

PREVENTING GROUNDFALL ACCIDENTS

When asked about what should be done to reduce the number of rock fall accidents in the coal industry, both miners and inspectors frequently cited the need for better training in this area. Several other strategies for improving training were also suggested.

A significant number of miners agreed that each of the changes proposed in statements B-1 through B-9 (table 5) would significantly help miners to avoid rock fall injuries. The three highest ranked changes were adding more support to bad areas of the roof, better training in proper methods of supporting the roof, and better training in the identification of roof hazards.

RECOMMENDATION TO COLLECT SURVEY INFORMATION

In order to formulate a good strategy for preventing roof and rib falls at a particular mine site, one needs to get an accurate diagnosis of the types of barriers that people are facing at that mine. Barriers that are quite significant in some mines are not at all a problem in other mines. Therefore, mine safety and training professionals should consider collecting survey information from the people who work at their mine to find out which barriers need to be overcome. The people who work underground every day are in the best position to help diagnose which barriers are the most troublesome, and they may also have some very good ideas about how these barriers can be overcome.

The Bureau of Mines has developed a detailed survey guide for collecting information about miner beliefs concerning the causes and prevention of roof and rib fall accidents. This guide contains a set of survey forms, and a set of detailed instructions about how to use these forms to conduct one's own survey. The survey requires approximately 30 min for participants to complete, and is designed for collecting information from groups of miners in a classroom setting (e.g., as part of annual refresher training).

The information one obtains from this survey can be used for a variety of purposes. The survey results can be used by trainers to help them determine the adequacy of the training they are giving miners on the prevention of roof and rib fall accidents, and how they might make improvements to this material. The survey results can be used in subsequent training sessions as an excellent source of material for group discussions. The survey results can also be used to help formulate recommendations to mine managers about what should be done (in addition to training) to prevent roof and rib fall accidents.

MSHA has assembled a set of materials to assist those interested in finding out how to collect survey information concerning roof and rib fall accidents from the miners at one's own mine site. These materials include:[5]

1. A survey guide that contains survey forms and detailed instructions about how to use these forms to conduct a survey of one's own miners.
2. A Bureau of Mines Information Circular that presents substantially more information about groundfall accidents than could be covered in this paper.
3. A 20 min videotape presentation of the research findings contained in this paper.

[5] To obtain copies of any of these materials, write to: National Mine Health and Safety Academy, Business Office, P.O. Box 1166, Beckley, WV 25802-1166. If you have any questions concerning the survey guide's use, contact the training specialist at the MSHA office in your district.

BLASTERS TRAINING MANUAL FOR METAL-NONMETAL MINERS

By Michael A. Peltier,[1] Larry R. Fletcher,[2] and Richard A. Dick[3]

ABSTRACT

The Bureau of Mines has developed blasters training material for the metal-nonmetal mining industry. The material is divided into 6 chapters and 47 modules, with each module covering a single topic. For example, the second chapter, which covers initiation and priming, is subdivided into nine modules. There is a module covering initiations systems in general, another module covering delay series, and one discussing priming. The remaining six modules deal with each of the six initiation systems.

The modules were structured to enable the mine training personnel to easily develop a site-specific blasters training program. Each module contains text material that comprehensively covers the topic, as well as a paraphrased section highlighting the major ideas of the text. Also included with each module are line drawings and test questions with answers.

The objective of this material is to increase hazard awareness and foster the use of safe blasting practices with the anticipated end result being accident-free and productive blasting.

INTRODUCTION

Based on accident data obtained from the Mine Safety and HealthAdministration (MSHA), most blasting accidents are caused by human error, lack of hazard awareness, or lack of general blasting knowledge.A lack of understanding as to how explosives function can contribute to higher mining costs because of inadequate fragmentation or lost production.

Federal regulations require that every person who uses or handles explosive materials shall be experienced and understand the hazards involved. Trainees shall do such work only under the supervision of and in the immediate presence of experienced miners. Federal regulations also require hazard and task training for miners. Most training given on mining property is based on experience at that mine and is done without the aid of adequate training materials. An improved and more meaningful blasters training program is essential in assisting operators to properly train blasters and meet MSHA training regulations.

The blasters training material was developed to aid industry in the preparation of a site-specific training course, and is based on a previous Bureau report.[4] It is the intent of the blasters training material to help the individual using explosives and blasting agents to develop a better understanding of the various aspects of blasting that contribute to a safe and efficient blast.

[1]Mining engineer.
[2]Mining engineering technician.
[3]Staff engineer.
Twin Cities Research Center, Bureau of Mines, Minneapolis, MN.

[4]Dick, R. A., L. R. Fletcher, and D. V. D'Andrea. Explosives and Blasting Procedures Manual. BuMines IC 8925, 1983, 105 pp.

PREPARING A TRAINING COURSE

The blasters training materials have been developed to be easily constructed into a site-specific and comprehensive blasters course. The material consists of discrete modules that contain text material, a paraphrased section, line drawings, and test questions with answers.

Individual pages have been divided vertically with the comprehensive text material on the left-hand side of the page. Each paragraph of the text material is numbered for quick reference. The right-hand side of the page consists of paraphrased text material with a main heading and a paragraph number. The person preparing the training course can read the paraphrased material quickly in order to grasp the main ideas of the text material. If an explanation is needed, the individual, by noting the paragraph number, can go directly to the paragraph that discusses a particular point.

Line drawings are included with the material to help illustrate specific concepts. The line drawings can be easily converted to overhead transparencies for use in the training course.

The first step in preparing a blasters training course is to determine what material must be covered. This can be accomplished by talking with the blasting supervisor and blasters, and by observing the blasting operation. To help determine what topics need to be covered in the course, a checklist is included with the material. The checklist is arranged to parallel the chapters. By completing the checklist the trainer will be able to locate the modules to be included in the course. For example, under the "Chapter One—Explosives Products" section of the checklist, if ANFO and emulsion are noted next to the subsection "Blasting Agents," by reading the list of modules in the table of contents under the "Chapter One—Explosives Products" section, the trainer will notice that module 4 discusses ANFO and module 5 discusses emulsions.

The second step is to gather the training material needed. The information gathered from the blasting personnel through the use of the checklist will indicate which modules should be included in the course. In addition to the modular material, slides and other visual aids from the actual operation should be used. Additional technical information concerning specific blasting products can be obtained from either the explosives supplier or manufacturer.

The third step is to write lesson plans for the course and arrange the training material into a cohesive unit. The writing of the lesson plans can be simplified by making extensive use of the paraphrased section in the modules.

Since the experience, knowledge, and ability of individual blasters vary widely, both the length and amount of material to be included in the course will have to be determined by mine management.

CHAPTER CONTENTS

CHAPTER ONE—EXPLOSIVES PRODUCTS

Purpose and Description

The purpose of this chapter is to help the blaster develop an understanding of various types of explosives. Chemical and physical properties of seven types of explosive products are discussed. Additional information explaining nine properties of explosives, used to determine how an explosive product will function under field conditions, is also covered. Material explaining how to select an explosive product is included in this chapter.

Objectives

Upon completion of this chapter, the blaster should be able to—

1. Give a concise explanation of the nature of various explosive products;
2. List the basic reactive ingredients of an explosive product;
3. Explain how the detonation pressure and explosive pressure cause the rock to be broken;
4. Explain the importance of oxygen balance as it relates to both the energy released and to the formation of toxic gases;
5. Describe the individual characteristics of the explosive products the blaster may be using;
6. Briefly explain why a particular product is being used at his or her operation;
7. State and explain nine basic properties of explosive products; and
8. Relate the basic properties of explosives with the types of explosive products being used on the job.

Chapter Modules

1. Chemistry and Physics of Explosives
2. Types of Explosives and Blasting Agents
3. Nitroglycerin-Based High Explosives
4. Ammonium Nitrate-Fuel Oil (ANFO)
5. Slurries, Water-Gels, Emulsions
6. Heavy ANFO
7. Primers and Boosters
8. Liquid Oxygen Explosives
9. Black Powder
10. Properties of Explosives
11. Explosives Selection Criteria

CHAPTER TWO—INITIATION AND PRIMING

Purpose and Description

The purpose of this chapter is to help the blaster develop an understanding of six initiation systems. The blaster will learn the various components of each initiation system, how the individual system functions, and the advantages and disadvantages of the six systems. Information about the two basic delay series and material concerning priming is also included in this chapter.

Objectives

Upon completion of this chapter, the blaster should be able to—

1. Name the three basic parts of an initiation system;
2. Explain the difference between high explosives and blasting agents as to their sensitivity to initiation;
3. State the difference between an instantaneous and a delay detonator;
4. List the various components of the initiation system he or she will be using;
5. Explain how the initiation system functions;
6. Explain how to check the final hookup of the system;
7. Discuss the potential hazards to the initiation system;
8. Give the definition of a primer;
9. Name some types of explosives used as primers;
10. Explain the proper procedure for making primers;
11. Explain why the proper location of the primer in the borehole is important.

Chapter Modules

12. Initiation Systems
13. Delay Series
14. Electric Initiation
15. Detonating Cord Initiation
16. Detaline Initiation System
17. Cap-and-Fuse Initiation
18. Hercudet Initiation
19. Nonel Initiation
20. Priming

CHAPTER THREE—BLASTHOLE LOADING

Purpose and Description

The purpose of this chapter is to examine proper blasthole loading techniques. The chapter discusses loading procedures for both small- and large-diameter blastholes. Also included in the chapter is material that not only discusses how to check blastholes for proper depth, water, voids, and obstructions, but how to mitigate these problems.

Objectives

Upon completion of this chapter, the blaster should be able to—

1. Explain why blastholes should never be loaded and why workers should retreat from the blast area during the approach or progress of an electrical storm;
2. Describe how to check the borehole for proper depth, obstructions, water, and voids;
3. Explain how to remedy problems, such as, improper borehole depth, obstructions, water, and voids;
4. State why stemming is important and how to estimate the amount of stemming needed;
5. Explain when plastic borehole liners or water-resistant cartridges should be used;
6. Explain proper technique for loading the explosive or blasting agent he or she will be using;
7. Describe the characteristics of the type of pneumatic loading he or she will use;
8. Explain the potential problem of static electricity if he or she is going to use a pneumatic loader; and
9. List the advantages and disadvantages of using bulk-loaded products in large-diameter blastholes.

Chapter Modules

21. Introduction
22. Checking the Blasthole
23. General Loading Procedures
24. Small-Diameter Blastholes
25. Large-Diameter Blastholes

CHAPTER FOUR—BLAST DESIGN

Purpose and Description

The purpose of this chapter is to examine the factors that influence safe and effective blast design. In addition to the discussion of design factors for surface and underground blasting, four controlled blasting techniques are also covered.

Objectives

Upon completion of this chapter, the blaster should be able to—

1. Discuss how geology affects fragmentation;
2. Name the most significant geologic features to consider when designing a blast;
3. Discuss the importance of a well-detailed drilling log;
4. Explain how to determine the burden;
5. Explain why geologic structure is the major factor in determining blasthole diameter;
6. Explain how collar distance affects fragmentation size;

7. Explain the relationship of collar distance to airblast and flyrock;
8. Explain the relationship between burden flexing and rock fragmentation;
9. Discuss the problem with either excessive or insufficient subdrilling;
10. Explain how spacing is determined;
11. Explain the advantages of millisecond delays;
12. Discuss two classifications of opening cuts;
13. Explain how to design an angled cut;
14. Explain how to design a parallel hole cut;
15. Discuss the two types of delays for underground blasting;
16. Name the two main advantages of using controlled blasting;
17. List the four primary methods of controlled blasting; and
18. Discuss the advantages and disadvantages of the various methods of controlled blasting.

Chapter Modules

26. Introduction to Blast Design
27. Properties and Geology of the Rock Mass
28. Surface Blasting
29. Underground Blasting
30. Controlled Blasting Techniques

CHAPTER FIVE—ENVIRONMENTAL EFFECTS OF BLASTING

Purpose and Description

The purpose of this chapter is to examine the environmental effects of blasting. The material will discuss flyrock, ground vibrations, airblast, and dust and gases. Methods to reduce the potential healthand safety hazards they may present will be discussed.

Objectives

Upon completion of this chapter, the blaster should be able to—

1. Explain the importance of conducting a preblast survey, maintaining comprehensive records, and good public relations;
2. Discuss the causes of flyrock;
3. Discuss methods to alleviate flyrock;
4. Discuss the causes of ground vibration;
5. Discuss design techniques to minimize vibrations;
6. State some methods to monitor ground vibrations;
7. Discuss the causes of airblast;
8. Discuss methods to monitor airblast;
9. List techniques to reduce airblast;
10. Explain why an adequate amount of time must be given for dust and gases to be diluted before returning to the blast site; and
11. List the two common toxic gases produced by blasting and list techniques to reduce them.

Chapter Modules

31. Introduction to Environmental Effects of Blasting
32. Flyrock
33. Ground Vibrations
34. Airblast
35. Dust and Gases

CHAPTER SIX—BLASTING SAFETY

Purpose and Description

The purpose of this chapter is to help the blaster develop a better understanding of blasting safety. This will be accomplished by examining a number of auxiliary blasting functions. A number of precautions related to previous modules are mentioned. Four accident types that occur frequently are also discussed.

Objectives

Upon completion of this chapter, the blaster should be able to—

1. Explain why a knowledge of all current blasting safety regulations is important;
2. Name the agencies that regulate and enforce the use and storage of explosives and blasting agents;
3. Describe the requirements for vehicles used to transport explosives and blasting agents from the magazine to the job site;
4. Explain the importance of marking the blast area, and keeping nonessential personnel away;
5. Explain when to check for extraneous electricity;
6. Discuss why electrical storms are a hazard regardless of the type of initiation system;
7. Explain the importance of proper primer makeup;
8. List a number of checks to be made before borehole loading begins;
9. Describe various methods to check column rise during borehole loading;
10. Describe some precautions to consider before and during the hookups;
11. Explain some good methods for blast area security;
12. Describe the potential hazards to check for when reentering the blast site after the shot has been fired;
13. Discuss methods for disposing of misfires; and
14. Discuss the principal causes of blasting accidents.

Chapter Modules

36. Introduction to Blasting Safety
37. Explosives Storage
38. Transportation From Magazine to Job Site
39. Precautions Before Loading
40. Primer Safety
41. Borehole Loading
42. Hooking Up the Shot
43. Shot Firing
44. Postshot Safety
45. Disposing of Misfires
46. Disposal of Explosive Materials
47. Principal Causes of Blasting Accidents

SUMMARY

Training material for metal and nonmetal mining has been developed by the Bureau. This program consists of 47 modules or topics under 6 major headings (chapters). The modules consist of a text and outline on a single blasting topic plus questions and answers. Supplementing the modules are a 73-item bibliography, a list of regulatory authorities and their responsibilities, additional information on MSHA and Office of Surface Mining, Reclamation and Enforcement, glossary, and 65 illustrations suitable for duplication and use as overhead transparancies.

Developed material will soon be available through MSHA's National Mine Health and Safety Academy, Beckley, WV.

OPERATIONS-BASED TRAINING STRATEGY FOR LONGWALL MINING

By R. Larry Grayson,[1] Michael J. Klishis,[1]
Ronald C. Althouse,[1] and George M. Lies[2]

ABSTRACT

A system that can be used to pinpoint the specific training needs of operations and assist in the design and upgrading of focused training approaches can benefit longwall mining. It can be directed at systematically correcting performance discrepancies at an individual, crew, or mine level, and also to challenge workers and management toward attaining improved performances. Such an approach involves a combination of features, such as diligence in monitoring and evaluating performances, thorough coordination in implementing changes, and effective use of operational data.

The Bureau of Mines, through contract with the Mining Extension Service of West Virginia University, has developed such a system, the training in operations program (TOP), that combines these features and ties longwall training directly to operational performance requirements.

The TOP provides a practical five-step system for managers to implement a focused training program that coincides with longwall productivity and efficiency goals. The system permits management to plan, organize, and schedule task training, cross training, and specialized longwall skills training of regular crews and backup personnel.

INTRODUCTION

Managers in the coal industry often wish they had a foolproof system for managing operational performance and managers in safety, training, and operations would like a system for upgrading training to match operational needs. A practical approach for managing operations and upgrading worker skills involves a combination of features, such as diligence in monitoring and evaluating performances, thorough coordination in implementing changes, and effective use of operational data.

The training in operations program (TOP) is a management system that combines these features so that managers can plan, organize, and direct longwall training efforts. It is an operations-based strategy that ties longwall training directly to operational performance requirements and guides management step-by-step in using operational data for improving safety and efficiency through training.

In a manner similar to the way management seeks to allocate and use human, technical, and support resources for more efficient longwall operations, this approach:

1. Provides an operator with an organized way to plan and execute training for developing proficient workers and for improving work practices on the longwall face,
2. Introduces guidelines and schedules for training of longwall workers and workers from different areas of the mine who are often reassigned to nonroutine tasks, and
3. Establishes operational performance criteria that guide the training of workers assigned to longwall panels and allow for timely evaluation of their individual performances.

This approach can benefit longwall operators threefold. First, it incorporates a problem-solving method for assisting management in pinpointing trainable operational concerns. Second, it helps managers make better use of training resources for upgrading and maintaining worker skills in a systematic way. Last, it emphasizes collection and analysis of data for assessing the impact of training on operational performances.

[1]Assistant professor.
[2]Curriculum designer.
Mining Extension Service, West Virginia University, Morgantown, WV.

TRAINING IN OPERATIONS PROGRAM: A METHODOLOGY

The Mining Extension Service of West Virginia University, under contract with the Bureau of Mines, developed the concept for the TOP on the basis of an 18-month assessment of training needs in longwall mining.

This operations-based training concept fits the traditional mine management system for controlling operational performances, but it directs managers in using operational data for improving worker proficiency and, hence, reducing downtime and accidents.

The model (fig. 1) consists of a five-step methodology that guides managers in developing a specific training strategy for resolving operational areas of concern.

The five steps, which will be described in more detail, are—

1 Developing a training strategy.
2. Planning the training program.
3. Scheduling and executing training.
4. Evaluating impact of training on operations.
5. Obtaining feedback and adjusting training strategies.

Through this process, TOP provides a practical way for managers to maintain compatibility between training and operations and to implement training according to established company policy, particular on-the-job training (OJT) practices, and operational timetables. Also, this system permits management to plan, organize, and schedule task training, crosstraining, and specialized skills training of longwall crews and otherworkers who are assigned intermittently to longwall tasks.

The model can direct management in making the best use of current longwall training options (Harold (1),[3] Jackson (2), Sprouls (3), and Riddell and Savage (4)). Also, it can help longwall operators bridge the gap between initial training by the manufacturer of the longwall equipment, which extends from installation of equipment and the first few weeks of operations, and task training or annual refresher training, which may meet the coal operator's cross-training requirements.

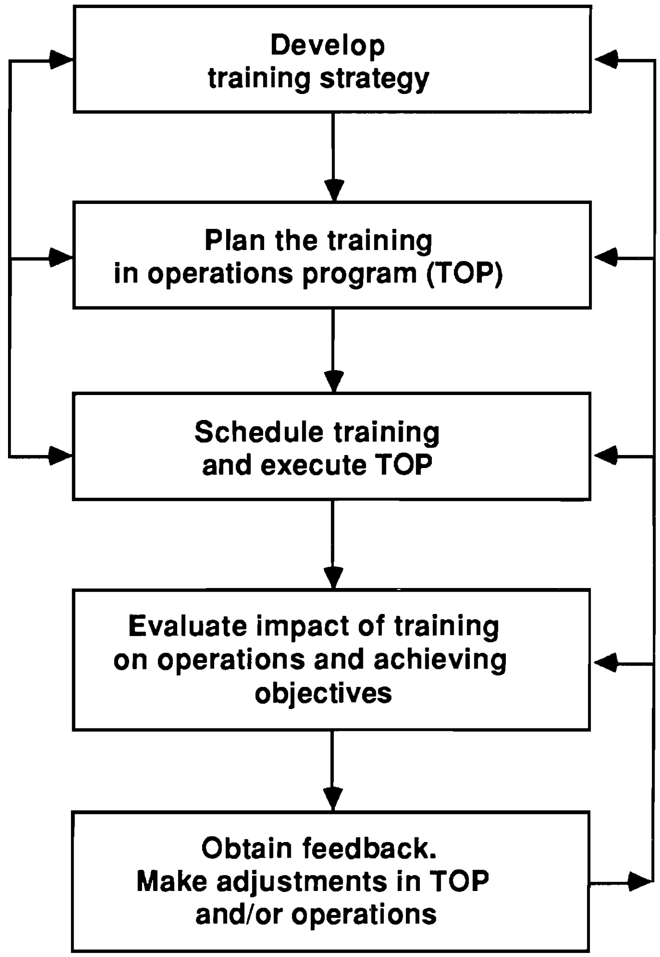

FIGURE 1.—Training in operations program (TOP) model.

TOP AND OPERATIONS-BASED DATA MANAGEMENT

As a systematic approach to longwall training, the TOP involves the use of operational data and related information for training purposes. Analysis of such data can help managers pinpoint real training needs and project operational benefits. With this strategy, mine management can also capitalize on existing knowledge and experience—often lost with informal training—and adjust training plans to meet operational demands.

The program organizes pertinent operational information according to three facets of longwall mining:

1. Work practices that often change according to the requirements of a system's technology and equipment modifications; panel design and dimensions, and mining or physical conditions.

2. Work (shift) organization that depends on the amount of time used for performance of production-related tasks, nonroutine tasks associated with downtime, and tasks required for servicing and maintenance of equipment.

3. Workforce requirements that derive from staffing and crew configuration, demographic trends of longwall crews, and the general or specialized training needs of machine operators and selected workers.

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

The three facets of longwall mining provide a useful framework for organizing data and information that affect longwall training. Each facet consists of several factors that influence both the content of training and the level of performance.

LONGWALL WORK PRACTICES

Work practices may vary widely according to technology, panel dimensions, and face conditions, although longwall operators have sought to standardize operational procedures over the years. Mine operators generally prefer a double-ended ranging drum shearer and shields for their longwall systems (table 1). This type of installation now accounts for nearly 85 pct of all longwall panels operating in 1986 according to analysis of recent studies (Sprouls (5)).

Preferred work practices often change as management makes modifications in the longwall system for safety and efficiency. Longwall operators also tend to implement new technology as it becomes available, phase out labor to reduce mining costs, and usually standardize work practices as changes are made in the system.

Longwall systems, which generally handle adverse physical conditions better than other mining methods, are still characterized by a number of common problems affecting work practices. These areas of concern are congested walkways, which restrict movement, especially at the headgate, flying and falling rocks, especially at shearer operator and shield worker locations; and tight clearance for workers assigned to cleaning rock-coal spillage, transporting supplies along the face, and performing nonroutine maintenance work (especially during downtime periods).

TABLE 1 - Longwall equipment utilization, 1974-84

	New installations						All installations operating	
	1974		1975-77		1978-82		in 1984-85 period	
	Number	pct	Number	pct	Number	pct	Number	pct
			DOUBLE-ENDED RANGING SHEARER					
Chainless haulage:								
Shield support	4	8	3	20	43	88	74	74
Chock support	1	2	0	NAp	0	NAp	0	NAp
Chain haulage:								
Shield support	6	12	8	53	3	6	6	6
Chock support	9	18	2	13	1	2	2	2
			SINGLE-DRUM RANGING SHEARER					
Chainless haulage:								
Shield support	0	0	0	NAp	0	NAp	2	2
Chain haulage:								
Shield support	7	14	0	NAp	1	2	1	1
Frame support	1	2	0	NAp	0	NAp	0	NAp
			SINGLE FIXED DRUM SHEARER					
Chainless haulage:								
Shield support	0	0	0	NAp	0	NAp	1	1
Chain haulage:								
Shield support	0	0	0	NAp	0	NAp	1	1
Chock support	3	10	0	NAp	0	NAp	1	1
Rope haulage:								
Chock support	2	4	0	NAp	0	NAp	2	2
			COAL PLOW					
Chain haulage:								
Shield support	2	4	1	7	1	2	8	8
Chock support	1	2	1	7	0	NAp	1	1
Frame support	7	14	0	NAp	0	NAp	1	1
Rope haulage								
Chock support	2	4	0	NAp	0	NAp	0	NAp
Frame support	3	6	0	NAp	0	NAp	0	NAp
			ALL CUTTING MACHINE SYSTEMS					
Total	48	100	15	100	49	100	100	100

NAp: Not applicable

TABLE 2. – Overview of longwall crew responsibilities

Scope of activity	Service–maintenance[1]	Startup[2]	On-shift duties: Cutting time	On-shift duties: Downtime	End of shift
HEADGATE OPERATOR					
Communications, coordination, transportation. Performs all tasks. Alignment done by a supervisor-shieldman.	Service duties, visual housekeeping.	Coordinates startup with shearer operator who gives OK and startup orders.	Coordinating role with supervisor and shearer operator. Performs all tasks. Monitors cutting speed, communicates with headgate operator on pass, both ways.	Special duties and tasks as instructed.	All shutdown tasks (except hydraulic pumps), does deenergize.
SHEARER OPERATOR					
Sequence of activities coordinates with many (e.g., startup,alignment, deenergize shearer, hydraulic hoses, fittings). Shields pressurized by shield mover.	Service duties, visual monitoring.	Coordinates with headgate operator key steps (e.g., all clear, panline, energize) under instructions from supervisor.	Discuss cuts with supervisor, coordinates with supervisor. Performs all tasks. Monitors cutting speed, communicates with headgate operator on pass, both ways.	None.	All shutdown tasks (except deenergize shearer and powerwater, done by headgate operator).
PLOW HEAD-TAIL OPERATOR					
Coordinates, checks activities with many workers at the face. Runs face equipment.	Usually mechanic-electrician or maintenance shift.	Coordinates startup with supervisor and electrician-mechanic, functioning as headgate operator. Information on height-depth from supervisor, tailgate operator, jacksetter.	Monitors sequence movement of panline, but not alignment, face crew aligns. Methane supervisor checks, reports to supervisor, face crew.	None.	Coordinates shutdown with supervisor, mechanic-electrician, and utility workers (deenergize locally).
SHIELDMAN-JACKSETTER					
Coordinates with supervisor and others on face. Performs all tasks. Often OK's with hydraulic supervisor or mechanic, headgate operator, electrician.	Usually, hydraulic supervisor, electrician-mechanic, utility worker.	Preoperational duties apply here too.	Coordinate-communicate between headgate operator, shearer-plow operator, moving shields and moving panlines (following operators).	Special concerns.	Communicates with headgate operator and shearer operator (except hydraulic pumps, electrician-mechanic-utility worker or supervisor turns off pumps).
MECHANIC–ELECTRICIAN[3]					
Special skills, qualifications.	Mechanic or 3d shift maintenance often does work.	Does ongoing permissibility checks, repairs equipment (as needed).	Does ongoing permissibility checks, repairs equipment (as needed).	Performs tasks as needed or instructed.	None.
UTILITY WORKERS					
Directed, instructed, assigned by supervisor. Performs all tasks. Assists operators, shieldman. Performs housekeeping setup tasks.	As directed, may do spot tasks (e.g., get materials). May assist servicing (e.g., grease, rockdust bits).	Involved with other workers.	Assist as ordered these workers headgate operator – shieldman tailgate operator – stage loader operator (construction crew stallman). May relieve shieldman. Performs tasks at all places on face or outby.	As directed, may do servicing, housekeeping, special instructions.	Directed, instructed, assigned to help head gate operator, shieldman, (tailgate operator) (e.g., shovels, rockdusts, servicing).

[1]Permissibility check.
[2]Includes preoperational checks.
[3]Or 3d shift maintenance

LONGWALL WORK (SHIFT) ORGANIZATION

Productivity and costs of a longwall system are tied in part to the efficient organization of work across shifts. The assignment of labor on a typical shift depends on the amount of time longwall crew members perform work related to production, downtime, and maintenance activities. Table 2 shows the responsibility of a longwall crew across a shift.

Longwall mining requires a great deal of coordination among workers and continuity in the performance of tasks. Workers have to perform assigned tasks in a prescribed way to achieve and maintain optimal operational efficiency. During downtime periods, work activities are influenced by the fact that the supervisor has to reassign workers and redistribute workloads.

Mechanical breakdowns, nonmechanical delays, and accidents can affect productivity drastically. The amount of available cutting time, according to an analysis of recent productivity studies (Peake, (6-7)), as shown in figure 2, company data, as shown in figure 3, and on-site observations ranges on the average from only 100 to 170 min per shift.

Based on productivity figures, mine operators generally must reassign workers a lot of the time to nonroutine tasks and/or maintenance work. Production periods still incur more injuries than startup or end-of-shift periods. However, nonroutine tasks during downtime can account for as much as 41 pct of reported longwall accidents.

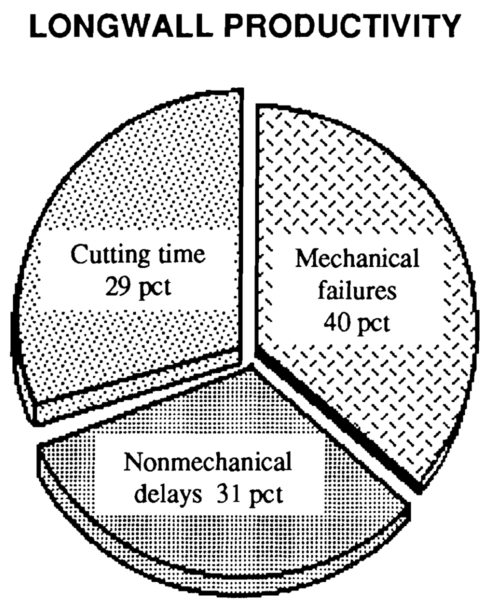

FIGURE 3.—Monthly summary of production and downtime for sample longwall mine.

Equipment-related work and environmental hazards affect the longwall crew generally across a typical shift. Falls of coal, pans-conveyors, roof support, and mining machinery are common agents causing bodily injury to the longwall miner. About 40 pct of the injuries were due to lifting, trips, falls, or handling materials.

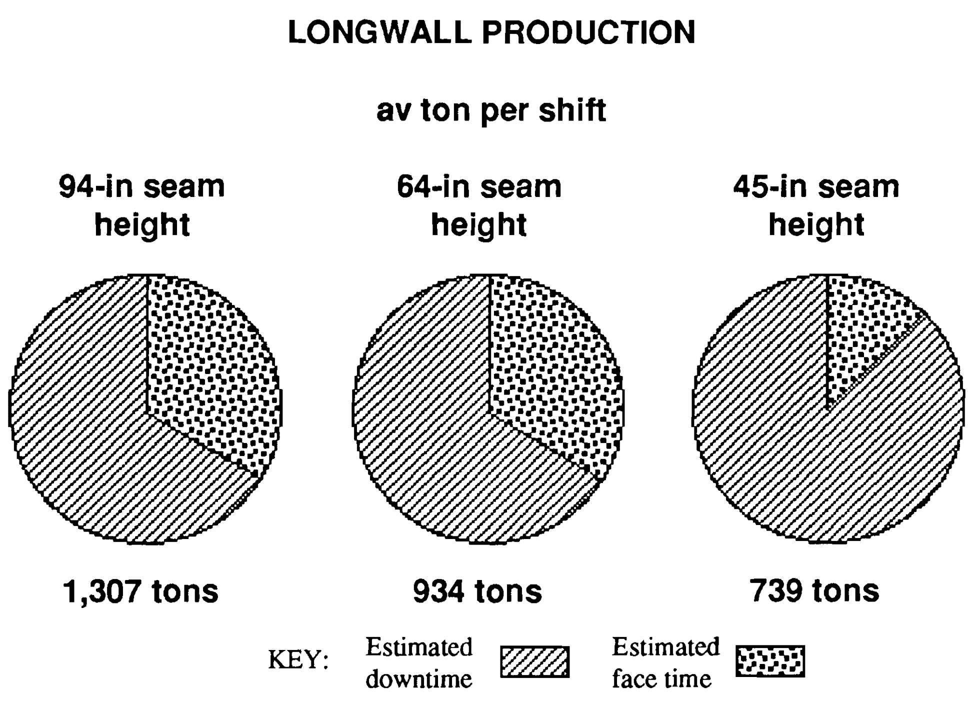

FIGURE 2.—Average longwall production per shift by seam height, and estimated production and downtime.

LONGWALL WORKFORCE REQUIREMENTS

Longwall mining is characterized by a veteran and experienced labor force. The average age among longwall workers studied is 35 yr and their average total mining experience is 10 yr.

A longwall crew (table 3) constitutes a relatively stable work group that remains intact over a long period of time (i.e., 14 to 16 yr), spanning a series of longwall panels and moves. Crew sizes range from 4 to 13 workers, down from 30 workers on pre-1970 panels, depending on the degree of control technology. Recent technological advancements (e.g., sensors, microprocessors) suggest that future longwall panels may require significantly fewer face workers.

Generally, workers tend to remain on the longwall panels in various occupations, often cross training among these jobs and bidding on other longwall jobs but not bidding off the longwall panel. These workers, however, experience a substantial number of injuries as they move from job to job on the longwall.

A range of accidents occurs to those workers who, on the average, have less than 5 yr experience (fig. 4) in their current job. This suggests that a worker may have extensive longwall experience with skills in one job, but may not possess the skills required of a new job assignment. This pattern holds true for all longwall workers, except mechanics, electricians, and supervisors.

Based on an analysis of accidents reported by 34 West Virginia mines operating 42 longwalls in the 1983-84 period, the cumulative lost time for reported injuries can result in a substantial loss. Nonfatal days lost (NFDL) at mines studied totaled 89 person-months in 1 yr and 93 person-months the other year or about 7 to 8 employee-years or more of work annually.

These facets of longwall mining provide a useful way to arrange and analyze operational data for determining specific training responses. In using these operational indicators, company personnel from various departments can define training strategies and choose the most appropriate options for improving operational performances.

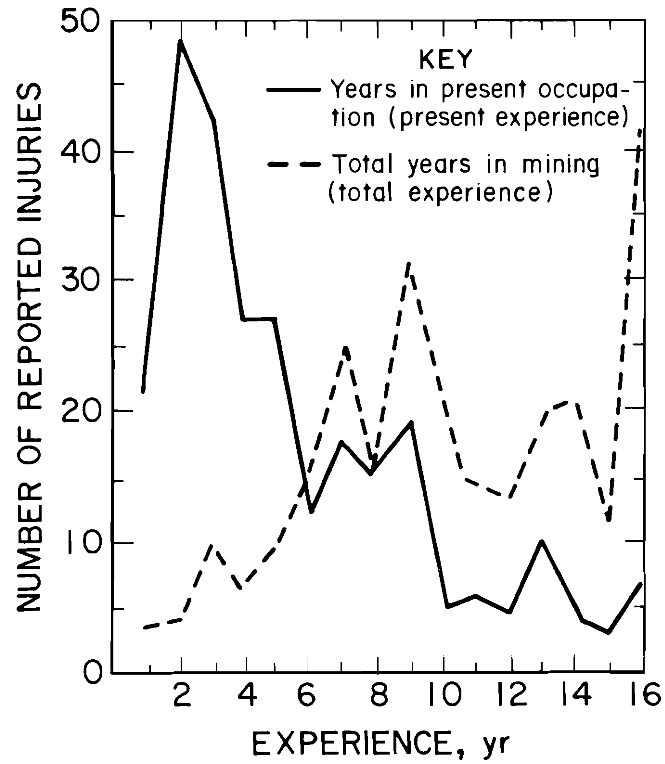

FIGURE 4.—Longwall experience versus overall experience in relation to nonfatal days lost (NFDL) injuries for miners in longwall occupations, 1983-84.

Next, this paper uses a scenario to show how managers can incorporate TOP into their normal decisionmaking structure and improve safety and efficiency of a longwall system through an operations-based training strategy.

Table 3. – Demographic characteristics of longwall workers experiencing injuries, 1983-84

	Average, yr			Injuries,	Average lost
	Age	Mining	Present job	pct	days per injury
Shear, plow operator	36	11.3	4.9	16.3	18.7
Shield, jacksetter	32	9.6	4.2	21.3	13.2
Headgate operator	38	11.0	5.1	5.8	36.0
Utility worker	36	9.2	4.2	15.9	23.4
Other labor	33	8.5	3.0	11.6	18.7
Electrician–mechanic	36	10.6	6.1	16.3	14.0
Management–salaried	37	11.8	6.9	12.8	20.4
Average or total	35	10.4	5.2	100.0	18.7

LONGWALL MANAGEMENT AND TRAINING

Longwall mining, as in most other mining methods, requires management to plan, organize, and control operations through the exchange of information in both formal and informal meetings. To allocate and use resources efficiently, managers must deal with data and information affecting labor, equipment, utilities, supplies, materials, and mine-specific conditions. Much of this information, as will be shown, may also be used and applied to develop a focused training effort (as needed) for company personnel.

For comparison purposes, a scenario will be used here to show the differences in using data between a traditional management system and a management system employing the TOP. The scenario will illustrate a problem discovered by a manager of mines on a routine, biweekly visit to a mine's longwall panel, which is equipped with a double-ended ranging drum shearer and two-legged shields.

First, a description of the problem: The manager of mines is observing production work along the panel, and notes that a shield mover is having trouble with baseplates digging into soft bottom, and that this problem, on occasion, leads to downtime. Also, the manager discovers that the worker is not placing crib blocks under the shields to help them stay on bottom, and tends to keep hydraulic valves open too long when resetting shields against the roof.

The manager learns from the longwall supervisor that this particular employee is a fill-in for the regular shield worker, that the worker had some previous experience as a fill-in for other members of the longwall crew, and that the worker was trained on moving shields for 2 h at the beginning of the shift. The supervisor, however, acknowledges that this fill-in worker has not mastered many of the fine points of the job.

At end of day, the manager notes that a total of 40 min of downtime occurred because of this problem, and that the fill-in shield worker was injured when a shield mashed the worker's foot into the bottom after it slid off the baseplate of an adjacent shield. First aid treatment and transportation from the panel interrupted production for another 30 min.

Now, compare the approaches as managers attempt to resolve the longwall problem.

MANAGEMENT AND INFORMAL TRAINING

Management decisions, including both immediate and deferred responses to a problem, may require training of hourly or supervisory personnel. Managers usually approach training within the traditional decisionmaking structure, and such training, which can be critical to cost-efficient longwall operations, often defaults to informal or impromptu methods (usually involving a supervisor), which often lack new information, effective communications, and guidelines for evaluation of performances.

Consider the case of the manager of mines from the scenario above. The manager recognizes several problems, such as costs of downtime, direct and indirect costs of accidents, and the company's practice of using partially trained workers as fill-ins for regular longwall crew members. What does the traditional management system offer, in the way of information, in order to solve the dilemma? What tools are available to help managers develop a planned, focused training effort to make operations more cost efficient?

Taking the problem back to the company's monthly review meeting, the manager of mines has to deal with the following:

The coal mine management system typically consists of three levels at which managers consider data and/or information regarding mining operations:

1. Monthly Divisional or Corporate Meetings.—Here managers review operational performances, discuss costs and productivity, determine capital and staff support of major work requirements, and analyze operational problems that potentially impact productivity.

Types of data and information generated for and by this level includes comparisons between established goals and present performance levels, labor assignment and supply delivery schedules, equipment maintenance and utilization plans, and other operational data (e.g., machine-panel designs, work practices).

2. Weekly Mine Planning Meetings.—These are designed to coordinate various work requirements among departments, to plan new jobs and weekend or idle work, follow up on progress of projects, and to examine operational problems and determine solutions.

At this level, information reflects operational performances, which may be directed at supporting a particular manager's position regarding a problem, costs of mining, and accomplishment of work according to new or revised schedules. Performance measures usually include productivity figures, downtime hours worked on support and maintenance, consumption of supplies, accidents and violations, and a line item summary of mining costs.

3. Informal Mine Meetings.—At this level, meetings may involve preshift coordination sessions at the supervisor staging area, where personnel relate and transfer information, generally in an unsummarized format, which bears directly on the previous shift's impact on the present status of sections and jobs.

Specific information exchanged includes physical conditions, equipment locations on sections or panels, status of supplies, materials, mechanical availability of equipment, and status of ongoing work (e.g., track-belt installation or removal, cable power center moves, construction of stoppings). At this level, such information determines jobs that must be accomplished simultaneously with production to ensure uninterrupted operations, and assists managers in updating and revising work schedules for efficiency.

At each stage in this decisionmaking process, personnel handle and review different kinds of data and information. Each level involves assignment of jobs, scheduling of work, or adjusting schedules based on updated information and input from various personnel to comply with operational objectives.

The manager of mines, given this system, has many ways to turn to resolve the recognized problem. However, how does the manager begin to state the case for either training of fill-ins or reduction of accidents to avoid unplanned downtime? What information is required to make the decision? Who does top management charge with the responsibility for training?

Without guidelines for incorporating operational data into decisions for training, managers may discuss a problem and then defer action or take immediate, ineffective steps to remedy the situation. If they make an immediate decision to train workers as fill-ins, how do they implement their plan? If they defer action because they need additional information, what helps them determine the types of data needed to be collected?

Here is what might have transpired in the scenario:

> After considering the problem, top management decides to train additional workers to serve as substitutes for regular longwall crew members. In so doing, the management team charges the supervisor with the training responsibility. With time at a premium, especially on the part of the supervisor, operational limitations often result in transfer of only the most basic aspect of job requirements to the worker (i.e., the functional aspects of performing a task or operating machinery).

Training of this nature quite often falls short on followup evaluation. Also, misinterpretation of intent, inability to implement actions, or inattention to detail may prevent proper implementation of desired instructions.

The training experience, hence, becomes one of self-learning. As the worker encounters problems, he or she focuses only on those essentials needed to maintain operational performance. Often, the trainee may have to ask the supervisor or a fellow worker for the proper way to handle a problem. Or, unfortunately, this person may use faulty reasoning in order to accomplish a sequence of tasks. Such an informal approach often leads to shortcuts as the worker tries to get the job done without understanding the potential for mishaps, which may result in downtime and/or injury.

FORMALIZING TRAINING WITH TOP

Features of the TOP provide a way for managers, beginning at the monthly review meeting, to focus on a specific concern such as the problem observed by the mine manager in the shield mover scenario. Working within the traditional management system, here is how TOP can systematically address the problems raised by the mine manager.

1. Developing a Training Strategy.—Step 1 of TOP (fig. 5) is initiated when the mine manager and other key personnel discuss the observed problem at the monthly review meeting. Only this time, managers have access to the TOP system and program guidelines. Here is what may transpire:

At the monthly review meeting, the manager of mines states the case for developing the skills of fill-in workers through training. The manager relates the issue to key personnel at the meeting: the superintendent of the mine, director of safety and training, controller, and the chief engineer.

The manager presents the facts: The injured worker was off 18 days and the accrued costs of the accident (e.g., direct and indirect expenses) is $4,600 so far, and the 70 min of downtime translates into nearly a $9,000 cost considering idle equipment and personnel. Then, the manager charges the mine superintendent with the responsibility to train a number of employees to be proficient as fill-ins for all longwall jobs, and asks for a report on progress in 1 month.

2. Planning Training and Evaluation.—Given an area of focus, commitment by upper level management, and keeping projected benefits in mind, key mine-level personnel initiate step 2 (fig. 6) and begin to formulate specific objectives. These objectives should be quantifiable as far as possible to permit evaluation of progress.

At the weekly planning meeting, the superintendent explains the situation and costs incurred to key personnel: longwall coordinator, general mine supervisor, chief electrician, outside sueprvisor, trainer and others. "Does a problem exist and, if so, how many workers should we train as fill-ins?" the superintendent asks of the group. The longwall coordinator suggests that four workers be trained as fill-ins for various longwall jobs, and that the mine could gain much operational flexibility as well as guard against a recurrence of the previous experience.

After obtaining a consensus, the superintendent charges the trainer and safety director to draw up a plan for training four workers and estimate total costs. The superintendent will choose the trainees after consulting with the mine supervisor, longwall coordinator, shift supervisor, and the mine committee.

In a related move, the superintendent requests the chief engineer to project potential benefits of this training approach (i.e., training employees as fill-ins for regular workers who were off or sick). "How much could we have saved over the past 3 months, in terms of production time lost and costs of accidents, if we already had well-trained workers to fill in as needed?"

Next, the trainer assesses training resources and their compatibility with specific objectives, tailors materials, and develops a tentative training plan and timetable. Also, management determines specific information and data to be collected during and after training, so that the company will obtain an accurate evaluation of the impact of training on operations and achievement of objectives.

This step requires thought on how and when to obtain data, analyze and summarize it, and present it to personnel throughout the organization. At this point, data and information must reflect performance levels resulting from changes and allow for comparisons between new performance levels and acceptable standards. (Types of data are referred to under weekly planning meetings.)

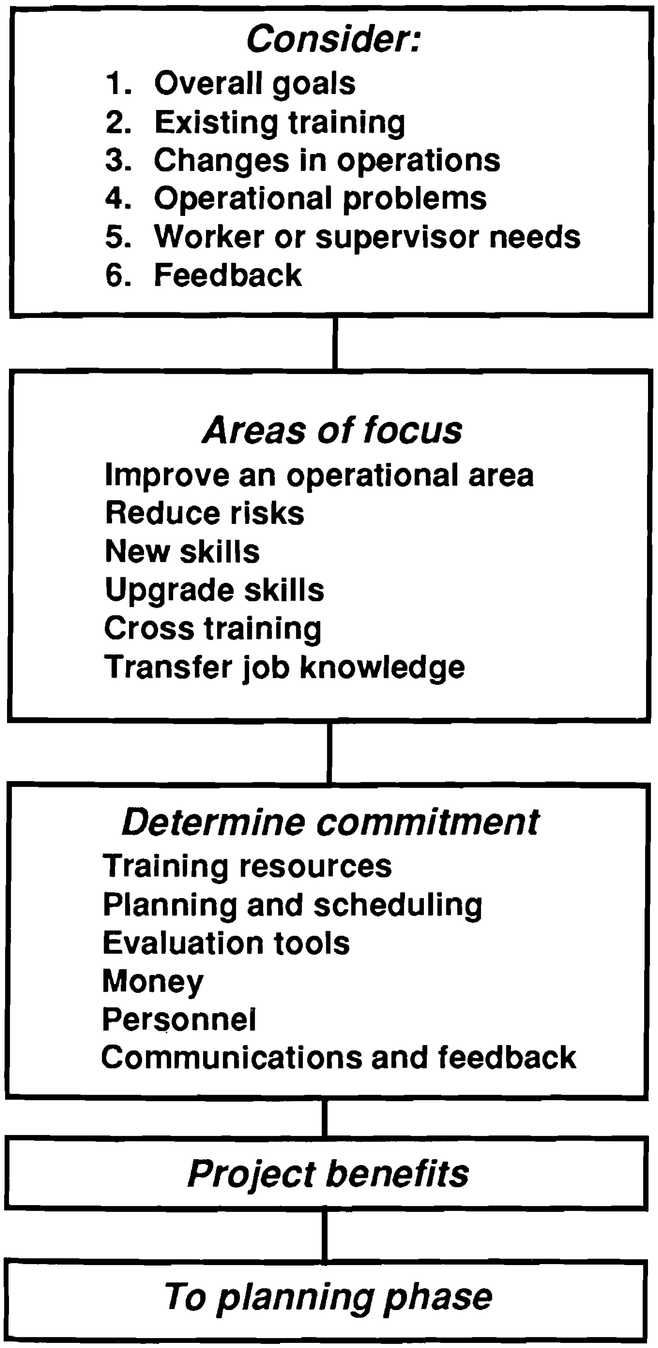

FIGURE 5.—Developing a training strategy.

3. Scheduling Training and Data Collection.—This planning process then leads to step 3 (fig. 7) of TOP. Management schedules and executes training plans, bearing in mind the need for types of training, specific times and trainees, operational contingencies, and potential revisions of the plan. Also, a schedule is set for specific data collection activities, which may require coordination between training and operations personnel.

4. Evaluating Data and Information.—This step (fig. 8) involves evaluation of the training impact on operations and in achieving specific objectives. Decisions focus on application of specific data analysis methods, and use of summary statistics or information for assessing the training impact.

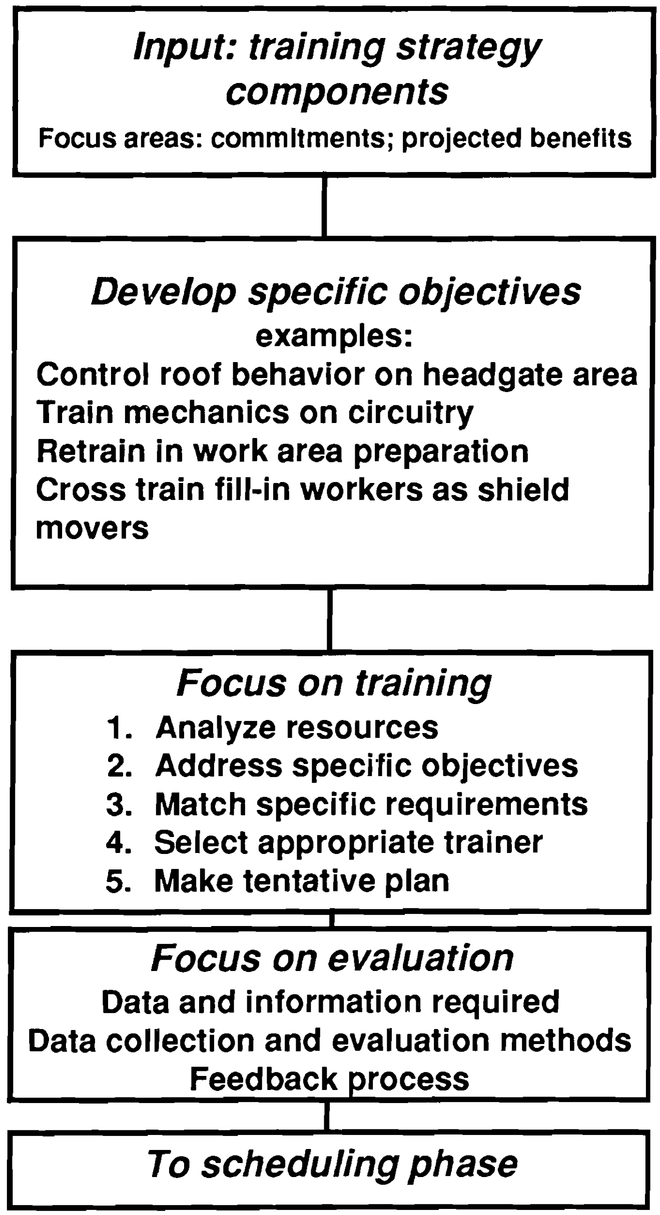

FIGURE 6.—Planning TOP.

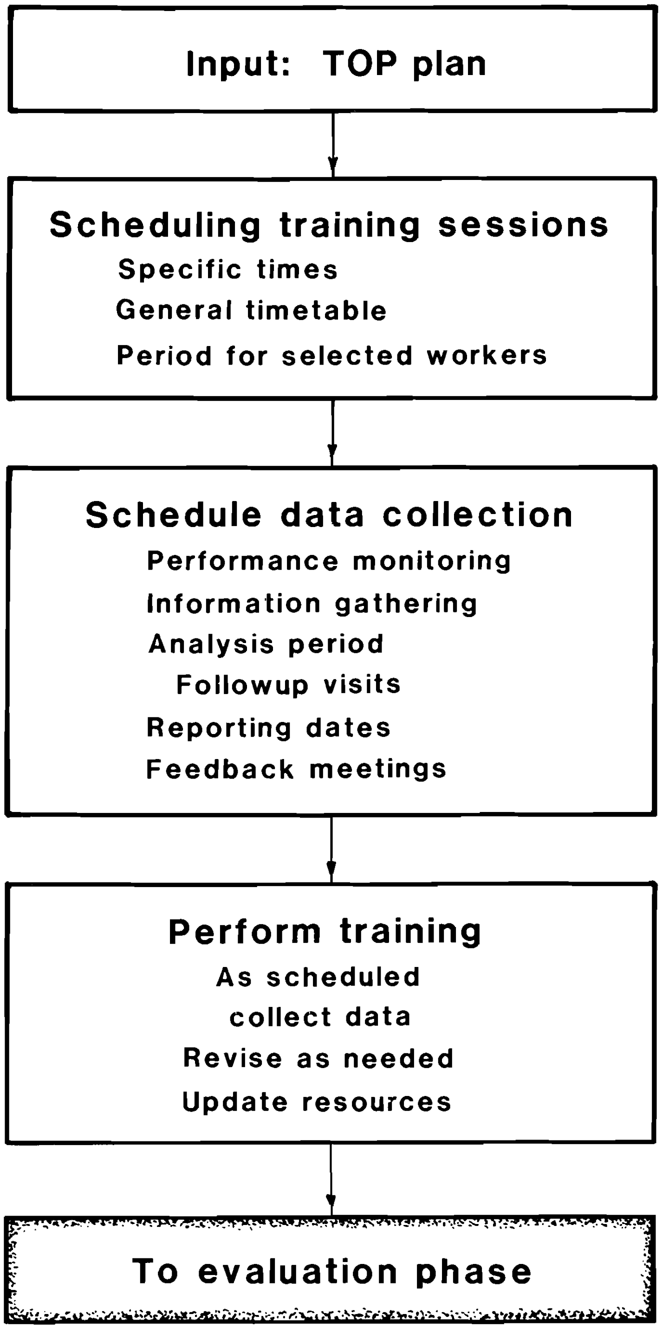

FIGURE 7.—Scheduling TOP.

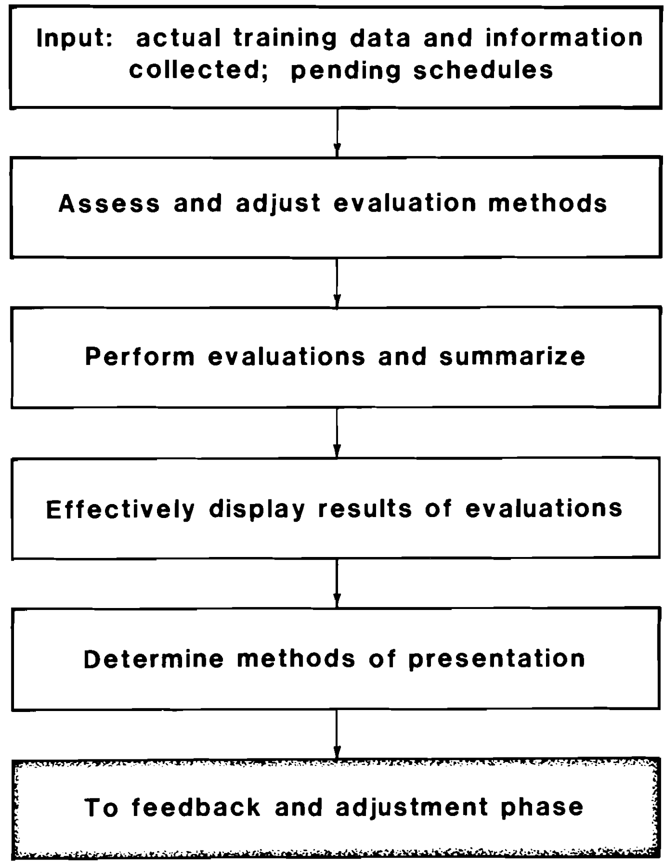

FIGURE 8.—Evaluation in TOP.

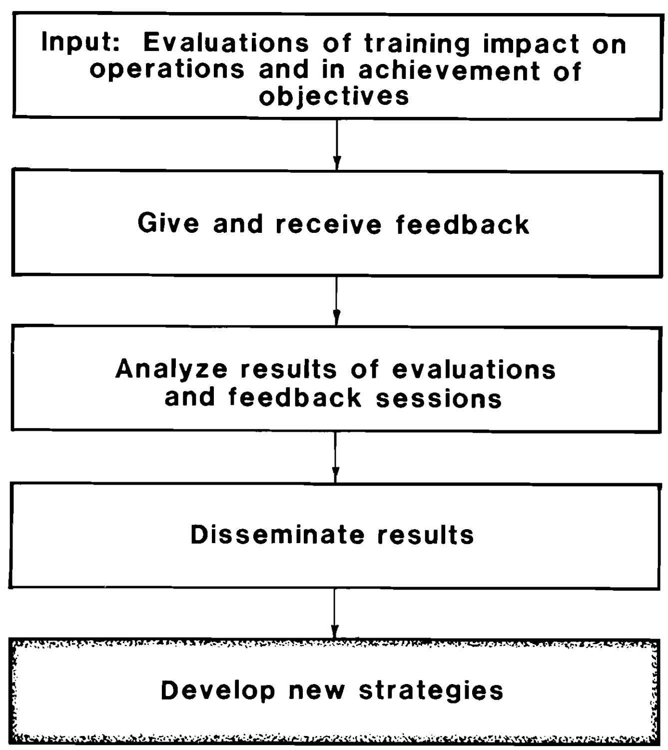

FIGURE 9.—Feedback in TOP.

Afterwards, the results of evaluation will be presented in various visual and graphic forms to distinct audiences within the company. Care must be taken to ensure that methods of presentation are compatible with the audience in order to elicit appropriate feedback.

5. Feedback and Adjustment.—Feedback from personnel at various levels is a critical function of the TOP system. This effort (fig. 9) provides information to operating and staff personnel regarding results from training and attainment of objectives, and obtains constructive comments from them

regarding shortcomings of training, the TOP methodology, formulation of plans or schedules, or practicality in tackling other areas of concern.

Following this interaction, managers can make adjustments to improve the program, amend objectives, continue as planned, or concentrate more heavily on other operational problems. Finally, dissemination of results to all appropriate levels in the organization ensures commitment from various personnel and keeps them abreast of results. Hence, this process will lead to new strategies (involving other areas of focus), new plans, and updated schedules in a systematic and continuous manner.

As the scenario depicts, TOP guides managers toward the achievement of safer and more efficient operations through a process aimed at mastering longwall changes or innovations and monitoring performance requirements. This leads to better control of operational performances and an effective way for measuring the training impact on operations.

In mastering changes, managers can adjust training to match anticipated modifications in work practices. This permits development of specific objectives which translate operational needs into training plans and schedules. By monitoring performance levels, management can evaluate results and make adjustments in training to meet operational needs. This results in the continuous use of operational data for upgrading the skills of the longwall workforce.

Thus, TOP provides managers with a way to better control operational conditions for high performance of a longwall system. It gives mine operators a perspective for developing a specific operations-based training strategy and for assessing the impact of training on safety and efficiency.

CONCLUSION

The characteristics of U.S. longwall mining, coupled with global coal market conditions, emphasize a necessity for management to plan and organize training to reduce and make effective use of unplanned downtime, develop worker proficiency and eliminate performance errors, and improve both the efficiency and safety of longwall technology. These are imperatives managers cannot afford to forfeit.

Longwall productivity and accident experience, as discussed in this paper, indicated that management can reduce downtime and lost workdays by paying close attention to detail and developing an operations-based training strategy to address operational problems in a systematic fashion.

The TOP offers a formalized methodology for guiding and assisting management in the application of data and information to improve operational performances as part of a company's normal decisionmaking process. It can provide benefits by allowing management to create a schedule of training requirements directed at—

- Individual or crew work practices,
- Familiarization of crew members with new or modified machinery or changing physical conditions, and
- Development of auxiliary personnel to perform longwall operational or support activities.

This operations-based strategy provides managers with a tool for improving operational safety and efficiency and for accomplishing various types of training as described in this paper. This approach to longwall operations can ensure accomplishment of intended objectives for developing proficient longwall workers and, in the end, higher productivity.

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MINER AND TRAINER RESPONSES TO SIMULATED MINE EMERGENCY PROBLEMS

By Henry P. Cole[1] and Staff, University of Kentucky[2]

ABSTRACT

This paper reports the results of a Bureau of Mines sponsored field test of 18 exercises intended to teach and assess miner proficiency in dealing with simulated mine emergencies. The problems are written from the perspective of the person working the exercise, and use latent image ink to provide feedback on any course of action listed as an alternative for each question. In this manner, the exercise takes the miner through decision points much like the ones he or she would be faced with in an actual emergency. Data collected from 1,500 underground miners in six States indicate that trainees overwhelmingly judged the exercises as being realistic and authentic, helpful in reminding miners of important things and in learning something new, of a suitable length, and highly enjoyable to work.

INTRODUCTION

When an emergency situation develops in the isolated environment of an underground coal mine, the well-being of the miners and the mine depends upon the early recognition of the problem and prompt responses to prevent, limit, or escape from the emergency. Civil and military aircraft flight crews face similar problems during inflight emergencies. Research suggests that paper and pencil and/or computer presented simulations of inflight emergencies can better prepare aircrews to recognize and cope with actual nonroutine critical events (Brecke (1),[3] Flathers (2), Giffin (3), and Jensen (4)). Similar extensive research suggests that training physicians and other medical personnel in medical diagnostic judgment and decisionmaking can be facilitated by simulation exercises (Babbott (5),Berner (6), Dugdale (7), Elstein (8), Gilbert (9), Jones (10),McGuire (11-13), and Rimoldi (14)). These types of simulations have come to be used extensively in the training of many kinds of military personnel in a wide range of problem solving tasks (Halff (15)). Simulation exercises are sometimes constructed using latent image (invisible) ink and paper and pencil tests. When the person makes a choice in a simulated diagnostic procedure, a special pen is used to mark in a space on the paper. A message appears and tells the test taker the consequences of his or her decision or action. Computers, role playing, physical models (manikins), and case reviews are also used to teach and assess proficiency in medical diagnostic and decision making skills. The extensive research literature about these simulations provides much information about how to teach and assess proficiency in fields where critical judgment and decision making are required for health and safety.

[1]Educational psychologist.

[2]R. D. Wasielewski, G. T. Lineberry, A. Wala, L. Mallett, J. V. Haley, W. E. Lacefield, and P. K. Berger, University of Kentucky, Lexington, KY.

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

LATENT IMAGE SIMULATION EXERCISES FOR COAL MINERS

Under a Bureau of Mines contract, researchers at the University of Kentucky Institute for Mining and Minerals Research, Behavioral Research Aspects of Safety and Health working group have developed similar simulation materials for underground coal miners. The materials are problems that require miners to recognize and cope with developing emergency events in underground mines.

Problem scenarios are developed based upon actual mine emergencies involving fires, explosions, water and gas inundations, roof falls, equipment failures, serious injuries, and sudden illnesses. The scenarios are authentic with respect to both the language and context of underground mining. As a problem unfolds miners must first gather information. They must then make judgments and decisions about what additional information they need, how to obtain the information, and ultimately what actions to take in what order. Proficient and efficient responses result in miners working the problem to prevent or minimize the accident or emergency. Errors in information gathering, interpretation, judgment, and decisionmaking lead to actions that worsen the situation. Thus, in the safety of a training room, miners experience vicariously the consequences of good and bad judgment and decisionmaking. It is not uncommon for a miner working the problem to end up "dead" or in deep trouble. When this happens, the miner is attentive to the information and procedures that are included in the remediation portion of the exercise. The remediation is intended to correct errors miners make in responding to the simulation problem. The intention is to improve the ability of miners for coping with the judgment and decisionmaking aspects of actual mine emergencies that may be encountered in the workplace.

TRADITIONAL ANNUAL REFRESHER TRAINING

For the past several years, members of the research project have attended many annual refresher training classes at many sites in several States both as observers and as participants. Observations of these sessions are sufficiently varied and lengthy to support the following generalizations:

1. Instruction for rote learning of information is the most common technique used by trainers.
2. There is a heavy reliance on the same sets of training films from year to year.
3. Trainees frequently fail to attend to the problem at hand, often dividing their attention between what is going on at the front of the room and interpersonal interactions with those around them.
4. When games are used, they usually focus on low-level factual recall of information—in addition, the mechanics of the games tend to compete for the miner and instructor attention and often detract from the content.
5. Many classes are characterized by relatively great amounts of time wasted, in the sense that it is spent on pursuits that are not goal oriented.
6. Parts of the typical daily program sometimes degenerate into complaint sessions with little of a concrete nature being accomplished.
7. The times when miners are most task oriented, attentive, and involved is when there is opportunity to discuss and resolve a problem in work procedures, or in discussing a hypothetical or actual first aid, fire, or other emergency.
8. Class members also tend to be alert and involved when opportunity exists for hands-on practice of specific skills or tasks such as simulated first aid treatment of victims, or the use of mine rescue equipment, or firefighting apparatus.

Instructional materials that have good potential use often fail to achieve that potential. For example, the Mine Safety and Health Administration (MSHA) Fatal Illustrations program has the potential to involve miners and instructors in productive indepth discussion, analysis, and planning. However, this potential is possible only when one or two fatal illustrations are selected for indepth attention. Yet, it is not uncommon for an instructor to show 20 to 30 of these fatal illustrations one after the other with an accompanying audiotape that presents the narrative for each accident. This method presents too much material, too rapidly, with little or no opportunity for miner involvement. Heavy use of training films one after the other, without time to think and talk about the film content, presents similar problems. Many studies have shown it is far more effective to focus on one or two issues that have direct relevance for the learners, and to encourage their dialogue and active involvement about these issues (Bransford (16), Cole (17), and Halpern (18)).

In summary, the content of annual refresher training is usually important and relevant. The opportunity for miners to become interested in the content presented and actively involved in discussing, debating, and generalizing it to their own experience is often limited. There tends to be little focus on problem solving and decisionmaking. There are, of course, exceptions and very capable instructors who teach effectively using a variety of methods that interest and involve miners.

Even when annual refresher classes are dull and uninteresting, in almost all cases the instructors are technically competent and respected by the miners in their classes. But both instructors and miner often appear bored by the typical pace, method, and topics of instruction.

DEVELOPING LATENT IMAGE SIMULATION EXERCISES ABOUT MINE EMERGENCIES

Using accident reports and the help of experienced mine safety personnel, a number of simulation exercises have been developed for teaching and assessing miner skills for responding to underground coal mine emergencies. The exercises are similar in structure to those used successfully to train for judgment and decisionmaking skills in emergency situations in medicine, aviation, and the military.

Problem scenarios accompanied by maps and illustrations are developed from reviews of actual mine emergencies reported in accident investigations. Sometimes scenarios are developed from the experience of miners, mine rescue team members, and mine inspectors. Usually, as a scenario unfolds there are predicaments. At some stages in the problem it is often unclear what series of correct actions is necessary to avoid or lessen the impact of an ongoing or impending accident. Each exercise presents a problem that unfolds over time. Just as in real life, the miner knows something of what has happened in the past, but cannot know what the future holds. However, just as in life, wise and canny miners can anticipate what actions, choices, and failures to act will likely alter future events, for better or worse. Constructing such inferences about a best course of action based on available data is what real life problem solving requires in mine emergencies. The simulation exercises are designed to approximate this situation.

Once they are developed, the realistic exercise scenarios are then discussed in small groups of experienced miners, emergency medical technicians, and mine rescue personnel. As the discussion progresses, good and bad options for coping with the problem at each of several stages emerge. This information is recorded and later used to construct individual questions and correct and incorrect answers to these questions for each scenario. Once developed, these prototype latent image format exercises are authenticated with small groups of other experts. The exercises are then revised, produced, and field tested with working miners in annual refresher training classes. All the exercises concern either first aid or self-rescue and escape situations.

The exercises are written as if the problem were developing and unfolding for the person who completes the exercise. The appendix to this paper shows the beginning of one first aid exercise. The basic background and problem information is presented succinctly in simple language. Simple line drawing illustrations appear in the printed exercise booklet and help to further describe the problem.

After studying the problem situation and illustrations, miners work the problems by reading a series of multiple choice type questions that appear in a problem book, with one question per page. A separate answer sheet contains sets of brackets that enclose each latent (invisible) image message for each course of action listed as an alternative for each question. When the miner makes a decision and selects a particular alternative, he or she colors between the brackets with a special marking pen. Immediately, the invisible ink becomes visible, and the miner is informed of the correctness or incorrectness of the response. Often, additional information that would normally result from that action is also presented. Thus, miners soon learn the consequences of their choice, the inadequacy or the value of a particular response, again similar to the manner in which such feedback is received for decision points and choices in actual mine emergency situations. In this manner, the exercise takes the miner through from 6 to12 steps in the problem where information must be gathered, decisions made, or action taken. The exercises are designed to teach as they simultaneously assess miner proficiency in dealing with the problems presented.

The appendix to this paper also illustrates part of another exercise, this one dealing with escape from smoke and gases originating in an unknown area of a mine. It too presents a complex problem in simple language and makes use of mine section maps to provide information needed to make decisions as the problem unfolds.

Thirty exercises like these have been developed to date. Once an exercise is developed in a latent image format it can be converted to a computer-administered format. Some exercises, especially in the first aid area, also lend themselves to role playing simulations with miners acting out the role of victim and first-aiders.

RESULTS OF FIELD TESTING

In 1986, 18 exercises were field tested in 84 annual refresher training classes at 20 sites[4] in six States with approximately 1,500 underground coal miners. Large and small mines, union and nonunion companies, high and low coal seam mining conditions, and various mining methods and techniques are represented in the sample. The basic demographic characteristics of this group of miners are presented in table 1. The distribution of age, gender, and job classification in this sample closely matches the observed distribution of these characteristics in other national samples of miners (Rockefeller (19)). The job classification miner includes all persons in regular and direct coal production jobs underground. The maintenance-technical classification includes mechanics, electricians, masons, carpenters, belt setup crews, surveyors, inspectors, engineers, geologists, and others who work underground but not directly in production. The supervisory-management classification includes all managers from

[4] The 20 sites were distributed across the Kentucky, West Virginia Pennsylvania, Virginia, Tennessee, and Illinois coalfields.

TABLE 1. - Basic demographic characteristics of underground coal miners from 6 states, 20 sites, and 84 annual refresher training classes in 1986

	Number	Mode	Mean	Std dev
Age	1,298	35	37.0	9.0
Experience	1,219	10	12.2	7.0
	Number	Frequency, pct		
Gender distribution:				
Male	1,256	97.3		
Female	35	2.7		
Job classification:				
Miner	1,031	65.9		
Maintenance/ technical	197	12.6		
Supervisory/ management	146	9.3		
Other	191	12.2		
Total	1,565	100.0		

the section foreman up through general mine foreman, superintendent, and top company management. The other classification includes clerical and office personnel, preparation plant and surface mine workers, accountants, laboratory workers, and others who work on the surface, but who sometimes participate in annual refresher training. Generally the classes were small, averaging about 16 miners (see table 2).

In addition to completing the exercise answer sheet, miners also completed a rating form and made written comments about the exercise. Miners at all sites judged the exercises very favorably, as can be seen by inspection of table 3. In particular, exercises were judged as being realistic and authentic, helpful in reminding miners of important things and in learning something new, to be about the right length, and enjoyable. In addition to the instructor's directions, the exercise written directions and graphics were judged as easy to comprehend, and the entire exercise as easy to read.

About 19 pct of the sample reported difficulty in understanding how to score their performance. Subsequent revisions of exercises have simplified scoring procedures and eliminated this problem. Inspection of individual exercise data revealed little variation in ratings of miners across the judgment categories. Generally, all exercises were rated uniformly high on all categories, except for clarity of scoring procedures.

TABLE 2. - Typical number of miners per class

Statistic	Value
Mode	17.0
Mean	15.5
Standard deviation	8.7

For each class administration, the instructor also completed a questionnaire that solicited information about (1) how the exercise was introduced and administered, (2) if the instructor modified the exercise in any way, (3) the observed frequency of reading problems among miners in the class as they worked the exercise, and (4) the instructor's judgment about key aspects of the exercise. The judgment categories included the degree to which miners were able to understand the instructor's directions, the clarity of written directions and graphics in the exercise, and the scoring procedures. The instructor also was asked to judge the appropriateness of the performance objectives, the relevance of the exercise for the annual refresher training class, and whether more exercises like these should be used in the future in other classes. Instructors also were asked to make comments to improve the exercise, and many did so, usually indicating they also would like to have more exercises developed for use in the future.

TABLE 3. - Rating of the validity, relevance, quality, and utility of 18 exercises in 6 States, 20 sites, and 84 annual refresher training classes in 1986

(Completed data sets, 1,213)

Miner judgment category	Yes	No
Exercise content is authentic	97.4	2.0
Working exercise will help me to remember important things	95.4	3.9
Learned something new from working the exercise	86.3	12.8
The exercise was too long	15.9	83.2
Liked working the exercise	89.0	10.1
Instructor directions clear	94.3	4.8
Written directions in the exercise are clear	86.1	13.0
Graphics in exercise are easy to understand	92.1	7.0
The procedures for scoring my performance are easy to understand	79.3	18.5
The exercise is easy to read	92.8	6.4

The summary data for the instructor's questionnaire are presented in table 4. Most instructors administered the exercise individually, in large part because they were requested to do so, to enable the correlation of miner performance scores with their questionnaire data. Given a free choice, the majority of instructors report they prefer to administer the exercises in small groups of from three to five miners per group. There are three reasons for this. First, the latent image answer sheets, which are consumable, last longer this way and more classes of miners can be taught with fewer of these materials. Second, most individual class members prefer to work the exercises cooperatively in small groups rather than individually. Once

TABLE 4. - Percentages of instructors in 84 classes responding to questions about exercise administration options

Administration format:	
Administered individually, 1 exercise booklet per miner	77.2
Presented exercise on transparencies while each miner responded individually	15.8
Presented exercise on transparencies while class members responded as a group	5.3
Used 1 exercise per small group in several groups per class	1.8
Used computer-aided instruction format	0.0
Explanation or direction provided:	
Explained how to work the exercise and use the latent image pen.	90.5
Made general comments about the exercise problem prior to miners working the exercise	69.0
Answered some questions as they worked the exercise	57.1
Led miners through the exercise questions, page by page	14.3
Provided other types of explanations and direction for working the exercise	3.6
Instructor action:	
Instructor did *not* modify the exercise	93.7
Instructor *did* use the discussion notes after the miners finished working the exercise	83.2

miners have worked an exercise as part of a small group, they usually resist attempts to have them work a second exercise individually. Third, in actual mine emergencies and in routine mine work, miners are generally required to work together. Working the simulation exercises in small groups may actually be more valid for teaching and assessing miner judgment and decisionmaking skills than having them work independently. Just as in real life the opportunity exists for the group decision at critical points to be informed or misinformed by members of the group with special status, authority, and expertise.

As shown by table 4, before administering the exercise about 91 pct of instructors explained the mechanics of working the exercise, and 69 pct commented on the problem. In about 57 pct of the classes, instructors reported answering some questions by miners as they worked the problem. Observation of field sites suggest most of these questions by miners concerned matters of procedure and clarification of the meaning of specific words and phrases to be consistent with local conventions, e.g. "Is a belt control line the same as our Air Alert system?" or "Is the expression dinner hole what we call the kitchen?" Only about 14 pct of the classes had an instructor who led the miners through the exercise in a lockstep fashion, a method that is generally distracting and annoying to trainees. About 94 pct of class instructors reported making no modifications to the exercise, and 83 pct reported using the instructor discussion notes provided with the exercise (see table 4). These data and many field observations suggest instructors administered the exercises as intended.

Instructors' observations also verified that miners have few problems in reading the exercises (see table 5). Instructors from 51 classes reported on this topic. These instructors reported that 55 pct of classes had no miners who experienced difficulty in reading the exercises. In about 28 pct of these classes, one miner experienced reading difficulty. Classes in which two miners experienced reading difficulty constituted 11.8 pct of these 51 classes. Only 5.9 pct of the classes reported three miners who experienced reading problems. No more than three miners with reading problems were ever reported. Table 5 summarizes these results of instructor observations of the frequency of miners' reading problems.

TABLE 5. - Frequency of miners who had difficulty in reading the exercise as reported by instructors, 51 classes

Miners with reading problems	Classes Number	Classes pct
0	28	54.9
1	14	27.5
2	6	11.8
3	3	5.9

TABLE 6. - Amount of time needed by the slowest class member to complete the exercise, as reported by instructor, 84 classes, minutes

Mode	30.0
Mean	43.1
Standard deviation	22.9

Inspection of table 7 reveals that instructor judgments of the relevance, quality, and clarity of exercise content parallel those of the miners. With the exception of clarity of scoring procedures, all aspects of the exercises were rated highly, as can be seen in the small standard deviations for each variable in table 7. The appropriateness of the performance objectives, the use of the exercises in annual refresher training classes, and the judgment that more exercises like these should be developed and used in the future received exceptionally high ratings from instructors.

TABLE 7. - Instructor ratings of exercise clarity, quality, objectives, and relevance, 84 classes

Rating category	Strongly agree 4	3	Strongly disagree 2	1	Mean	Std dev
Miners understood--						
Instructor directions	52.6	43.6	2.6	1.3	3.47	.62
Written directions in exercise	46.8	44.3	8.9	0.0	3.38	.65
Graphics in exercise	65.4	33.3	1.3	0.0	3.64	.51
Scoring procedures	26.9	29.5	24.4	17.9	2.63	1.11
Performance objectives are appropriate	72.2	25.3	2.5	0.0	3.67	.52
Exercise fitted well with annual refresher training	87.2	10.3	2.6	0.0	3.84	.43
More exercises like these should be used in the future	91.0	7.7	1.3	0.0	3.90	.35

TABLE 8. - Exercise list and word count

Exercise[1]	HT	OBJ	[2]PB	MAS	DN	[2]AS	[2]LIA
Apparent Diving Accident	306	217	938	496	1,068	203	300
Arnel V Beam	1,218	267	728	471	1,098	185	294
Bob Hall[2]	300	147	1,134	570	918	244	333
Bennie J Floyd	308	169	665	407	798	181	230
Bubba	295	234	1,786	1,372	1,850	226	1,172
Cleo C Pike	Rev						
Cleo C Pike Simulation[3]	3,011	0	0	NAp	0	0	0
Cecil	278	228	1,766	1,114	2,393	248	872
Cutthrough Ventilation Arrangement	312	408	2,140	1,225	2,951	473	807
Douglas O Tacket	278	142	950	506	915	219	294
Delta Mine Cutthrough[4]	NA	262	1,974	NAp	3,121	500	NAp
Drainway Entry	294	264	1,208	840	932	176	671
Fix-It	309	287	668	612	1,108	114	507
Harry Hastings	295	PB	1,264	566	1,232	223	353
Harry Harlan	299	163	985	447	1,150	199	254
Harry Harlan Simulation[3]	3,222	0	0	NAp	0	0	0
Hot Shuttle Car	308	141	1,151	929	1,206	228	708
J. J. Johnson.	309	200	1,159	663	1,219	140	530
J. J. Smith.	300	201	1,227	790	1,365	243	555
Jupiter Mine Fire	Inc						
Low Coal Fire	315	271	1,699	1,312	1,843	306	1,097
Marvin R. Letcher	309	316	1,829	971	2,002	167	810
Marvin R. Letcher Simulation[3].	3,587	0	0	NAp	0	0	0
Persephone Mine Explosion.	300	148	966	497	685	199	305
Roof Fall Entrapment	308	160	1,706	793	1,122	267	533
Thurman "HAP" Anderson	309	320	2,553	1,474	2,247	193	1,288
Traumatic Head Injury.	316	194	1,383	827	1,085	234	1,288
Vulcan Mine Ignition.	308	258	2,308	1,279	1,755	158	1,128
Vulcan Mine Recovery	1,295	323	2,395	1,449	3,638	199	1,257
Water Line Repair	309	408	1,538	894	962	138	763

AS Answer sheet.
DN Discussion notes.
HT How to use this exercise.
Inc Exercise is incomplete.
LIA Latent image answers.
PB Problem booklet.
Rev Exercise under revision.
MAS Master answer sheet.
NAp Not applicable.
OBJ Performance objectives.

[1]Except as noted, all exercises have a latent image format.
[2]Only parts read by trainees.
[3]Role play simulation format.
[4]Essay format.

When developing the exercises, a major concern was to keep them short. Most similar simulation exercises used in other fields tend to be much longer and often require as much as 2 or 3 h to complete. In annual refresher training classes the available yearly time for instruction is only 8 h. Any materials that are likely to be used must be well-organized, brief, and time efficient. The exercises meet these criteria. Instructors reported the time required for the slowest member of their classes to complete the exercise. The mean time of about 43 min reported in table 6 is actually longer than the typical time needed by the typical miner. The standard deviation for this variable is large for two reasons. First, exercise length varies quite a bit. Some exercises are long and others are short, as can be seen from inspection of table 8. Second, there is wide variation in the reading speed and comprehension of any group of adults, including underground coal miners.

WHY THE EXERCISES ARE EASY TO READ

Another major concern early in the project was that many miners would not be able to or would not want to read long written paper and pencil exercises. From the beginning, the exercises were designed to minimize demands upon reading speed and comprehension. Their design was also informed by the large amount of recent research in the area of story grammar and reading comprehension. This research has established that the structure and organization of written passages is more critical to a person's motivation to read the material and the ability to comprehend it, than the particular words used in the passage. Basically, well-organized prose materials that have a story line or plot, that deal with emotive laden content, that present dilemmas and predicaments, and that are cast with contexts that are common to the reader's own life experience are compelling reading and result in good comprehension (Anderson (20), Bower (21), and Mayer (22)). All exercises developed were designed to meet these criteria for the design of good prose material.

Other information also explains why the exercises are easy to read. First, although the problem content is often complex, the exercises are written in simple and direct language. Experienced specialists in the design of instructional materials typically rewrite and simplify exercise wording after these are initially developed by technical personnel such as engineers, emergency medical personnel, and experienced mine rescue specialists. The rewriting of initially developed exercises to conform with standards of good narrative structure, clarity and simplicity of language and directions must not alter, change, or detract from the technical content and purpose of the exercise. A team effort and a willingness to cooperate in exercise construction is essential.

An analysis of the readability level of three early but representative exercises was carried out using the University of Kentucky Composite Readability Analysis program. This program carries out seven independent estimates of the completed school grade level equivalent required to comprehend

TABLE 9. - Estimated reading difficulties in grade level equivalence of representative exercises compared to MSHA Fatal Illustration program narratives

Estimation formula	Harry Harlan[1]	Water line repair problem[2]	Vulcan mine ignition[3]	MSHA fatal illustration program
Spache	4	4	4	([5])
Dale-Chall	10	7	7	11th grade.
Raygor	7	4	4	Estimate not valid.
Fry	4	5	7	Professional.
Flesch	([4])	([4])	([4])	College senior.
Gunning-Fog	([4])	([4])	([4])	College.
SMOG	7	7	8	College.

[1]First aid exercise.
[2]Self-rescue and other rescue and escape exercise.
[3]Methane ignition, rescue, escape, and first aid exercise.
[4]Below formula range and cannot be calculated.
[5]Above formula range, and cannot be calculated.

the samples of text material analyzed. A fourth analysis was carried out on the narrative portion of samples from the (MSHA) Fatal Illustrations program. The results of these analyses are shown in table 9. The three representative exercises were found to have reading difficulties at the upper elementary and junior high school level, while the MSHA Fatal Illustrations narratives were found to require eleventh grade or higher educational levels of reading skill. It should be noted that all samples were corrected for the specialized mining jargon words that appear in both the simulation exercises and in the MSHA Fatal Illustration narratives. The difference in reading levels between the simulation exercises and the MSHA narratives are not related to the absence or presence of special technical words, but to the simplicity, directness, and clarity with which complex ideas are expressed.

Table 8 provides yet additional evidence that helps explain why the exercises are easy to read. The number of words per exercise is small. Little reading is required to work completely through an exercise. This is accomplished by precise use of simple and direct language, and by the use of appropriately placed graphics throughout the exercise as the problem unfolds. Furthermore, the bulk of the entire exercise component is not read by the miner in the annual refresher training class. Rather, the trainee reads only the problem booklet questions, the answers from which to select, and those latent image messages from the answers selected. The alternative choices to a question, as well as the invisible latent image feedback on the answer sheet, also are terse and to the point. Much effort is required during the design phase of an exercise to achieve this cogency.

INDEPENDENT OBSERVATIONS OF EXERCISE ACCEPTABILITY

Throughout the field testing, a primary problem faced by the project staff was to supply company management and instructors with the number of exercises and answer sheets they desired. For research and development purposes, only about 100 to 200 data sets were needed for each exercise. Yet company trainers often wanted from 500 to 2,500 copies of specific exercises, so that all miners in their organization could be trained. It is clear that the exercises are perceived as appropriate, worthwhile, and effective instructional tools by those who plan and teach annual refresher training classes.

Frequent observation of refresher training classes by project staff members also independently confirm the summary data presented in tables 2 through 5. Miners almost always are very attentive and interested in the problem being worked. During the discussion period that follows working the exercise, miners actively participate, often challenging points and choices made in the exercise itself, or those made by their colleagues and the instructor. Members of the class almost always explicitly relate and generalize the content and predicaments presented in the exercise problem to their own mines and experiences. The class frequently runs overtime extending into the lunch break, the end of the day, or the next class as miners continue to engage in lively debate and discussion about the problem. During breaks and lunch hour, miners have frequently been observed to continue their discussion of the exercise problem.

Another observation relates to the emotive involvement of miners in the exercise problem. The level of thinking and dialogue stimulated by the exercises is almost always sophisticated and technical. Yet, it is also passionate and emotional as miners and trainers debate what should or should not be done, under various circumstances, and why or why not. In short, the exercises engage the full attention of miners and stimulate high levels of thinking about, and discussing, ways to cope with and prevent mine emergencies.[5] Many studies have shown it is precisely these types of emotional and cognitive involvement with classroom presented material that learners see as authentic and relevant. Furthermore, while most classroom learning tends to be inert and not applied by the student to real life situations, classroom instruction that engages the active interest and involvement of learners makes what is learned accessible to the learner. When the content is accessible the learner tends to apply skills and knowledge learned in class to relevant aspects of his or her personal work and life (Bransford (16) and Halpern (18)).

In summary, both miners and trainers are fascinated with the exercises, would like to have more of these included in annual refresher training, become emotionally and intellectually involved in the problems, easily generalize and relate the problem content to their own experiences, and believe working the simulation exercises will help them cope more effectively with similar real-life emergencies. Company management and instructors would like more exercises, feeling that they stimulate high levels of interest, motivation, and involvement of the miners in annual refresher training classes.

Two broad generalizations can be drawn from the observations and data from the initial field test sites. First, the exercises are time efficient. An entire problem from introduction to feedback can be completed in approximately 1 h, with little or no time wasted on non-goal-directed activity. Second, exercises are motivating to the miners who work them. At each site, regardless of physical conditions or competing concerns, the part of the program devoted to exercise administration was characterized by concentrated effort and a high level of interest on the part of both trainers and trainees. There are three possible reasons for these observations.

[5]A more detailed account of the effects of the exercises on miner and instructor interactions and behavior is presented by reference 23.

First, the technique used in presenting the problems is intriguing. Although latent image technology has been in existence for several decades, few individuals are exposed to it on a regular basis. Therefore, it is novel and perhaps physically appealing to those who are interested in how objects work. However, there is no doubt that the novelty would soon wear off if that were all the exercises offered. The latent image technique can be considered an attention getter, but it is not the reason miners are willing to spend 1 or 2 h working and debating a problem. The major appeal of the exercises derives from the conformity to good instructional design criteria for both the construction of narrative materials, and for the effective presentation of classroom learning activities and materials.

A second factor in the apparent success of the exercises is that they provide concrete things for the trainees to do. Unlike training films and rote instruction, the problems do not allow passivity on the part of the miners. In order to get the task completed, class members must become involved. In addition, each person soon finds out that his or her opinion matters. The trainee owns the problem, in a sense, and the outcome depends very much on that person's judgment and choices. As in the workplace, the exercises allow the participants to exchange ideas and debate courses of action; either before or after the fact. The entire mode, therefore, evokes some of the same intensity of behavior that occurs in real-life situations where miners seek to anticipate, cope with, or reflect upon an emergency situation.

The preceding point underscores a third aspect of the exercises being field tested. They reflect authentic situations-the same kinds of predicaments miners talk about in the workplace and in other settings where they get together. Field observations indicate miners continue discussing facets of the exercises during breaks and at slack moments in other phases of the training program. This indicates that just as the workers do not tire of speculating on the things that went wrong when actual accidents or disasters occur, they do not grow tired of working exercises such as those now being developed. An advantage of the exercises over real situations is that each problem contains solutions and recommendations based on factual knowledge and expert authority, whereas informal efforts to reconstruct actual accidents after they have happened are often based on incomplete or erroneous information.

CONCLUSION

Simulation exercises for teaching and assessing proficiency in coping with underground coal mine emergency situations are a novel approach for annual refresher training classes. Yet, similar though longer and more open ended simulations have been used for years for training mine rescue teams and mine management personnel in mine emergency response procedures. The present project draws upon previous research in simulation problems in medicine, aviation, and the military. It includes as well the expertise in coping with underground mine emergencies that is found among experienced miners and mine rescue personnel. It also draws heavily from the recent research concerned with the construction of motivating and easy to comprehend narrative materials, as well as other research about the design of instructional strategies that make learning interesting and what is learned accessible to the learner in practical contexts. The simulation exercises that result are intended for working miners. They focus on the perceptions, information, judgments, decisions, and actions working miners must exhibit to prevent, recognize, and control nonroutine emergency situations. The setting is at the working section. The options are those available to working miners. Initial field test results of these 18 exercises have been encouraging. These latent image and other formats for simulation exercises have potential for increasing the relevance and quality of annual refresher training.

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APPENDIX. – PORTIONS OF A FIRST AID AND A MINE EMERGENCY EXERCISE

Marvin R. Letcher Exercise

Background

8 entries are being driven in 42 inch coal.

Eleven miners are working on Section 001.

The portal is 4,000 feet outby the face.

It is just after lunch. (Marvin ate a big meal.)

The EMT normally on this section is absent today.

You are trained in basic first aid but <u>not</u> as an EMT.

The top in this section is generally drummy and poor.

The roof bolter has an ATRS.

Problem

You are the pinner operator. You are bolting the roof in the #2 entry at the face. Your helper, Marvin R. Letcher, has gone out ahead of the bolter to mark the roof. You yell at him to get back. He almost gets back to supported roof when a piece of draw slate falls trapping both his legs. (See Figures 1 & 2 on page 9.) Marvin is lying face down screaming. The roof is dribbling across the whole entry just past the last row of bolts. Now, turn to page 4 and answer the first question.

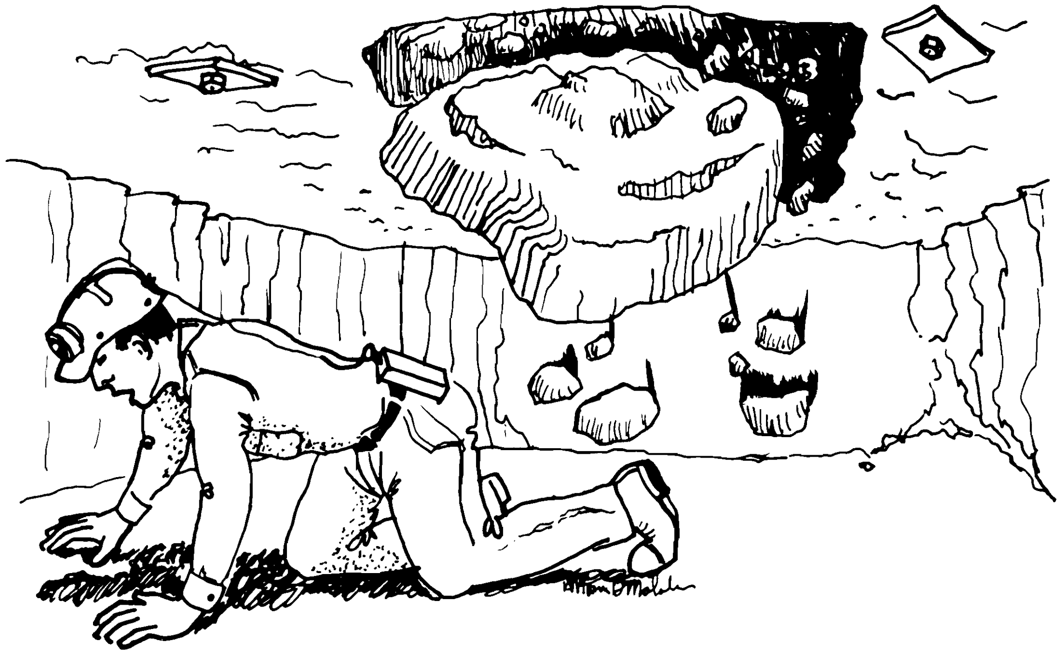

FIGURE 1.—Draw slate falls from roof.

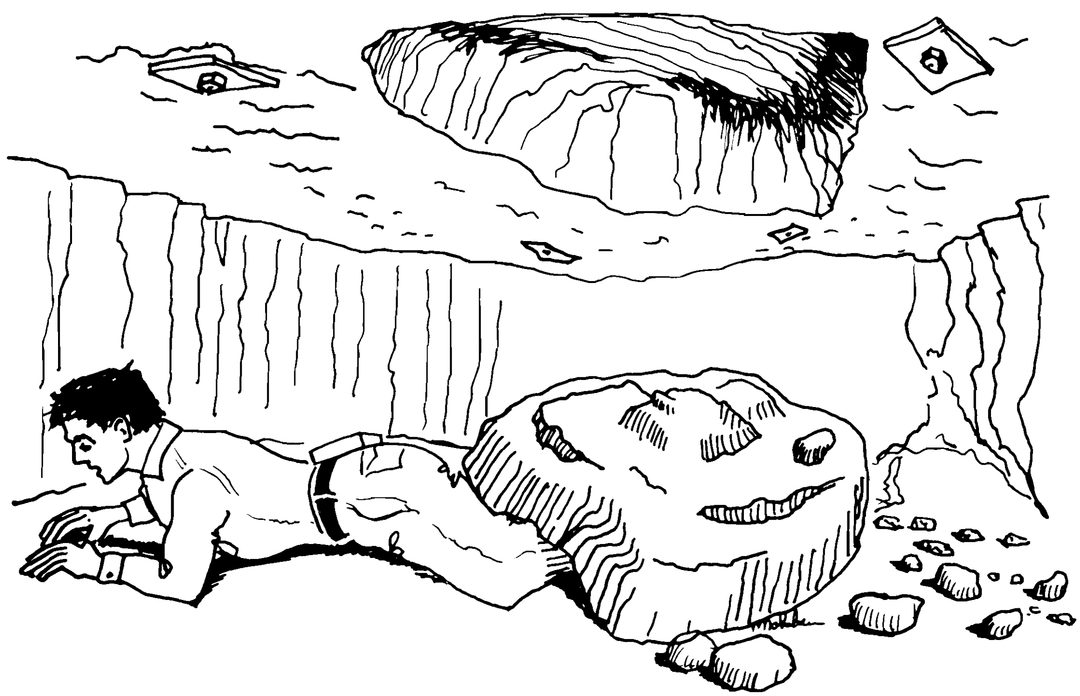

FIGURE 2.—Draw slate hits Marvin's legs.

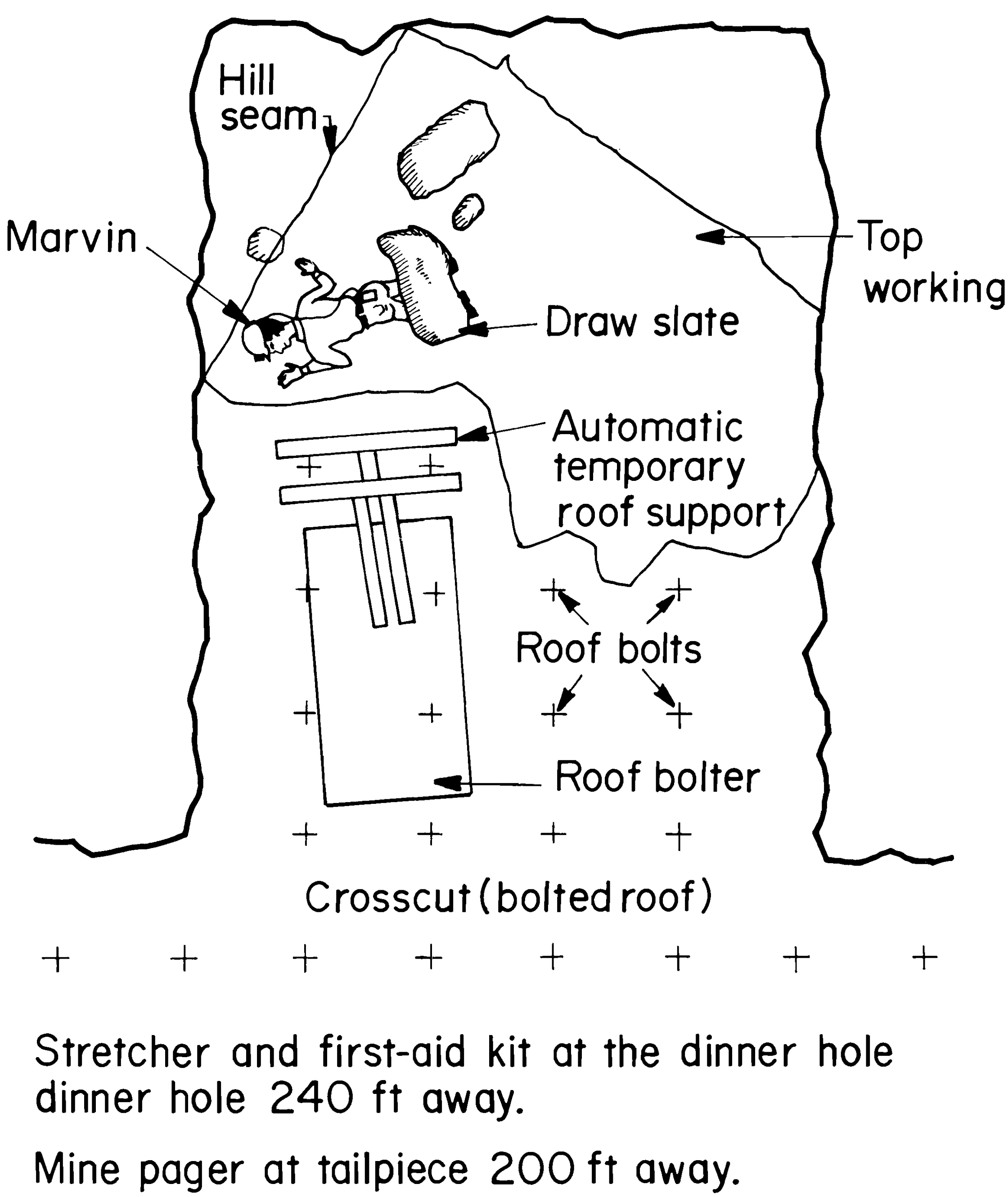

FIGURE 3.—Details of Marvin's position.

Question A

You yell for help. Three other miners come quickly. Marvin's legs are under the slate. His head is near the left rib. The roof bolter is outby his position about six feet. The ATRS is in place. (See Figure 3 on page 5.) The top continues to work. What would you do now? (Choose only ONE unless directed to "Try again!")

1. Grab a couple of slate bars. Have the other three miners help you pry the rock off Marvin's legs.

2. Get the head of the roof bolter under the corner of the rock and lift it gently off Marvin's legs.

3. Move close to Marvin to check his injuries and begin first aid immediately.

4. Leave the bolter and the ATRS where they are. Set roof jacks and timbers from the ATRS toward and around Marvin.

5. Lower the ATRS on the bolter. Tram the bolter ahead and then raise the ATRS over Marvin.

6. Tram the roof bolter out of the entry. Then tram a scoop in so you can lift the rock off Marvin with the scoop bucket.

Question B

You have now supported the roof with two jacks and three posts. Using slate bars and a jack, the three of you have lifted the slate just enough to free Marvin's legs. The top continues to dribble across the whole entry. What should you do now? (Choose only ONE unless directed to "Try again!")

7. Have your buddies grab Marvin by his belt and shirt while you grab his pants leg above and below his left knee. Pull together and slide him out from under the rock sideways on his stomach.

8. Get a board or some other object to serve as a splint. Put the board between his legs. Then gently tie his legs together before moving him.

9. Reach under the slate. Grab him by his boots and jerk him out sideways by his feet.

10. Leave Marvin under the rock. Give him first aid in this position until he has been fully immobilized and can be moved without further injury.

Master Answer Sheet for Marvin R. Letcher Exercise

Use this answer sheet to mark your selections. Rub the special pen gently and smoothly between the brackets. Don't scrub the pen or 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.

Question A (Choose only ONE unless directed to "Try again!")

1. [Risky! This may hurt you, the others, and Marvin. Try again!]

2. [Good idea, but the head is too big to fit under the rock. If you try to lift the rock]
[this way it may slide, slip, or fall and hurt Marvin more. Try again!]

3. [This action places you and Marvin in danger. Try again!]

4. [Correct! With the roof supported, you can now help Marvin. Do next question.]

5. [When you start to lower the ATRS, more slate falls. This action places you and]
[Marvin in danger. Try again!]

6. [When you lower the ATRS and begin to tram the bolter outby, more slate falls.]
[Now Marvin is in more trouble and you can't get to him. Try again!]

Question B (Choose only ONE unless directed to "Try again!")

7. [Correct! This procedure would be the fastest and least harmful way to move]
[him. Do next question.]

8. [This would endanger him and you. Try again!]

9. [This method of moving Marvin could cause further injury. Try again!]

10. [Risky and impossible. You can't work on him under the rock. This action also]
[places you and him in danger. Try again!]

Question C (Choose only ONE unless directed to "Try again !")

11. [His airway has to be O. K. He is screaming. There is a more important first]
[step. Try again!]

12. [Marvin probably needs help before being transported. Try again!]

13. [Correct! This protects everyone. Color the box under answer 14.]
[ ]

Cecil Exercise

Background

The mine, which is above the water table, is wet and has a 52 inch seam.

This is an 8 entry supersection, with 2 continuous miners, and 2 shuttle cars.

You (Cecil) are a continuous miner operator on the West Mains Section.

You are slim, strong, and in good shape (5' 10" and 145 lbs).

Big Tim, your helper, is overweight and in poor physical condition (6' 2" and 275 lbs).

The shuttle car roadway is littered with a large accumulation of loose coal and coal dust.

Problem

You and Big Tim have just trammed the continuous miner to the face of the #1 entry. Your boss comes by and tells you that one shuttle car with a damaged cable is stalled between #3 and #4 in the last open crosscut, and the other is stuck near the feeder. You and Big Tim decide to replace a few worn bits while waiting. While pulling the bits, you smell something burning. Tim tells you the smell is probably just from heat shrinking the boot over the splice on the shuttle car cable. After installing the bits, you go to the mouth of the #1 entry to establish face ventilation. Your eyes begin to burn and water. You look down #1 and across to #2 and see a cloud of thick, black smoke. The smoke is going by the mouth of #1 and out the return. You immediately yell to Tim and tell him about the smoke.

After studying the map on page 8, turn the page and answer the first question.

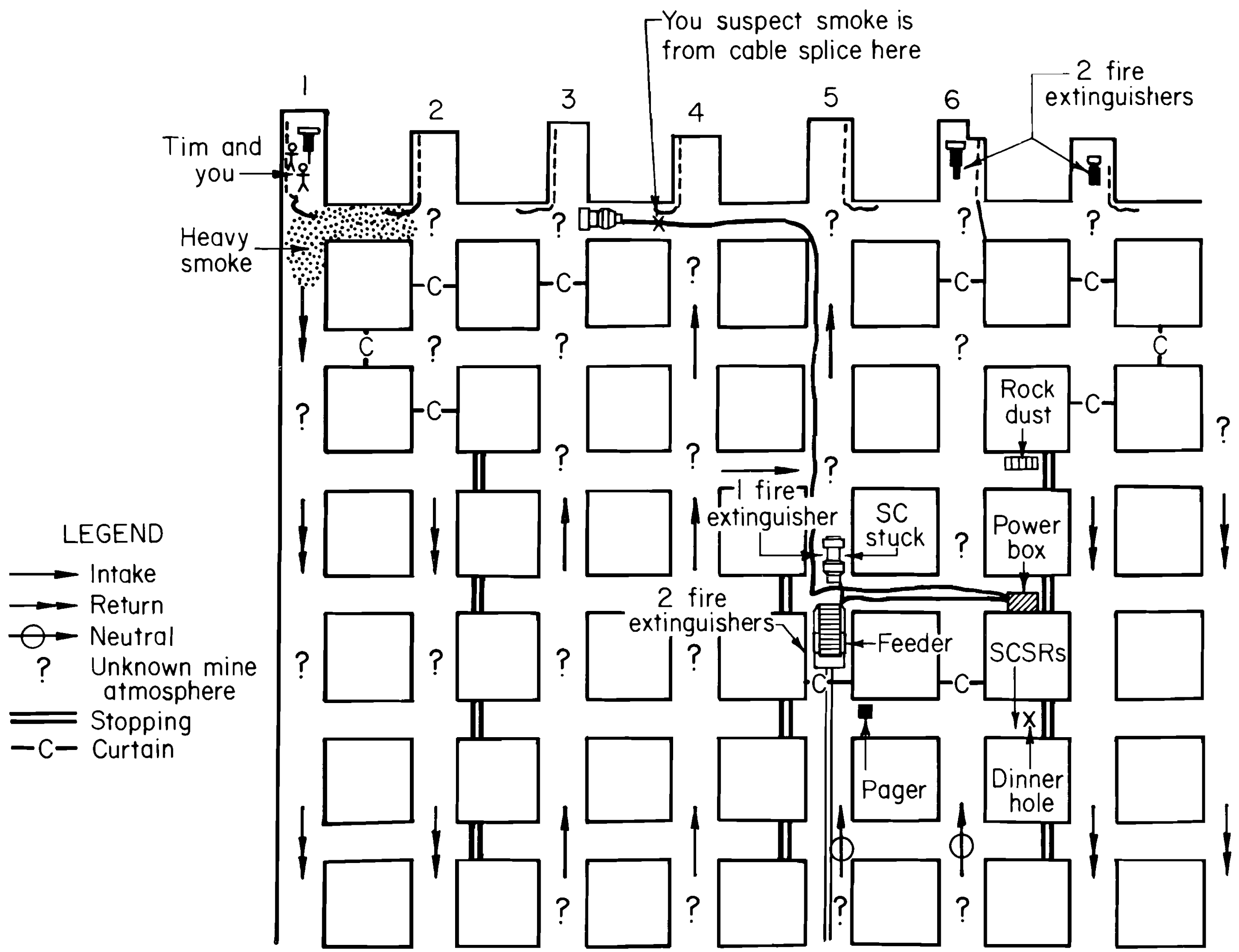

FIGURE 1.—Your position and Tim's position on the section, with the smoke cloud. You can see the possible locations of smoke marked with question marks.

Question A

After telling Tim about the smoke, what should you do first? (Choose only ONE unless directed to "Try again!")

1. Take your filter self-rescuer off your belt and have it ready in case you need it.
2. Sit down and wait for instructions from your face boss.
3. Put on your filter self-rescuer and tell Tim to do the same.
4. Take a deep breath and head for intake air quickly.

Question B

As you are putting on your filter self-rescuer (FSR), Big Tim tells you that he has left his FSR on the other miner, which is broken down in the #6 entry. What would you do now? (Choose only ONE unless directed to "Try again!")

5. Finish putting on your FSR, but stop and think before taking further action.
6. Share your FSR with Tim by taking turns breathing through it, and dash through the smoke.
7. Tell Tim to stay put. Finish putting on your FSR and go across the section to get Tim's FSR.
8. Leave your FSR off and wait for help with Tim.
9. Offer your FSR to Big Tim and have him go for help.

Master Answer Sheet for Cecil Exercise

Use this answer sheet to mark your selections. Rub the special pen gently and smoothly between the brackets. Don't scrub the pen or the message may blur. Be sure to color in the entire message once you make a selection. Otherwise you may not get the information you need.

Question A (Choose only ONE unless directed to "Try again!")

1. [You shouldn't do this unless you plan to put it on now. Try again!]

2. [He's probably down at the feeder. You need to act now. Try again!]

3. [Correct! Carbon monoxide may be present. Do next question.]

4. [This is very dangerous! You and Big Tim may die. Try again!]

Question B (Choose only ONE unless directed to "Try again!")

5. [Correct! A "snap" decision could prove fatal to both of you. You are not yet in]
[smoke. Do next question.]

6. [This would be difficult to do, and you would likely become separated in the]
[smoke. Try again!]

7. [There is a more critical first step. Try again!]

8. [Although "misery loves company," it is important that at least one of you is]
[protected from carbon monoxide. Try again!]

9. [Should it be necessary for someone to get through the smoke quickly, it should]
[be you rather than Tim. Try again!]

Question C (Choose only ONE unless directed to "Try again!")

10. [The effects of carbon monoxide do not depend on physical condition. Try]
[again!]

11. [This will not protect him from carbon monoxide. You still don't know the]
[source or extent of the smoke. Try again!]

12. [Smoke is slowly drifting in toward the face. Tim would soon be overcome. Try]
[again!]

FIRST AID ROLE PLAY SIMULATIONS FOR MINERS

By H. P. Cole,[1] R. D. Wasielewski,[2] J. V. Haley,[3] and P. K. Berger[4]

ABSTRACT

Simulation exercises designed to strengthen miners first aid patient evaluation, problem identification, and first aid treatment skills were developed and evaluated over a 2-yr period. The exercises are based on the work of Ohio State University and University of Kentucky researchers under Bureau of Mines contract. The design characteristics of these simulations are described in this paper. An example exercise is provided as an appendix to this paper. Using these materials, instructors can adapt the procedure and methods to develop a wide variety of other effective first aid simulation exercises.

Field tests of the new exercises suggest that the simulations (1) are seen as authentic and realistic problems by miners and instructors, (2) actively engage the interest and participation of miners, and (3) teach important first aid diagnostic and problem identification skills, as well as standard first aid treatment procedures. Performance data from the exercises confirm miners lack of proficiency in first aid diagnostic and evaluation skills. Training with realistic simulations, like those researched and described in this report, may increase miner proficiency for coping with actual first aid emergency situations.

INTRODUCTION

This paper provides practical information for instructors who teach first aid to miners in annual refresher training classes. After reading the paper and examining the materials in the appendix, instructors who choose to do so can develop similar simulation exercises for other first aid problems. The paper also provides background information about the design of these types of simulation exercises and presents data about their effectiveness.

The first section reviews the role of simulation exercises in teaching critical skills. Miner experience with simulation exercises, like mine rescue contests, is then discussed. Then, the inexpensive Ohio State University simulation method developed by Gilbert (1-2)[5] is described. Its potential application to the training of miners is noted. Results of the University of Kentucky studies of miner first aid strengths and weaknesses are then presented. Implications of these findings for the improvement of first aid training of miners are discussed.

The next part of the paper describes the design of new first aid simulation exercises for miners. The exercises emphasize initial diagnostic evaluation of the victim's injuries through hands-on primary and secondary surveys, as well as the performance of standard first aid treatment procedures once the injuries have been identified and treatment priorities determined. Then, the field testing procedures used to evaluate one exercise are described. The miner evaluations of the exercise are presented along with information about the miner performance.

The last part of the paper interprets the data from the field tests of the new simulation exercise. Suggestions for the use of such exercises are provided.

[1]Professor, Department of Educational and Counseling Psychology.

[2]Associate professor, Lexington Community College.

[3]Professor, Department of Behavioral Science.

[4]Professor, Martin School of Public Administration. University of Kentucky, Lexington, KY

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

SIMULATION EXERCISES FOR TEACHING AND TESTING CRITICAL SKILLS

Simulation tests of real life problem solving are often an effective way to train and assess proficiency for dealing with emergency situations. Simulated emergencies can be realistic and motivating. They can also demand a broad range of responses from the individual including (a) recognizing cues that indicate an emergency is developing or underway, (b) gathering additional information to diagnose the nature and extent of the emergency, (c) making decisions about various courses of action that should be taken, and (d) implementing and carrying out appropriate procedures to alleviate or control the emergency (Distlehorst (3)). For these reasons, well-designed simulation exercises can mimic many aspects of emergency situations. Consequently, a simulation exercise can provide opportunity for persons to learn and practice critical skills needed to cope with actual emergencies.

Because of these characteristics, simulation exercises are widely used in training professional and technical persons for responding to emergency situations. Elaborate interactive computer-controlled human patient simulators, patient actors, computer-generated patient evaluation problems, and paper and pencil latent image patient care and management problems (PMP's) are frequently used for training physicians, nurses, and dentists to diagnose and treat medical illnesses and emergencies (Babbott (4), Dugdale (5), Farrand (6), Fleisher (7), Jones (8), McGuire (9-10), Norman (11), Pryor (12), Saunders (13), and Umbers (14)). Similar simulation techniques are used in assessing proficiency of emergency skills of aircrews (Flathers (15), Giffin (16), Jensen (17)), power plant operators (Hunt (18)), and other technical personnel (Olsen (19)).

Figure 1 outlines a simulation exercise developed for the proficiency testing and refresher training of industrial and laboratory workers (Olsen (19)). The simulations are carried out as staged accidents in actual work locations. Human actors and simple props are used to stage a more or less realistic accident scene. (In one training program described by Olsen (19), animal blood and entrails obtained from slaughterhouses are used as props to simulate major injury accidents to workers.)

The simulation begins when workers discover the simulated accident and begin first aid care for the victim. The discovery may be with or without prior knowledge of the trainees as part of a planned training activity. Although they may provide a realistic context for teaching and assessing proficiency in critical first aid skills, such full-scale work location simulation exercises are difficult and costly to arrange. Yet these and other types of simulation exercises provide experience with situations workers and first-aiders rarely encounter otherwise. A main purpose of such simulations is to maintain proficiency in nonroutine, infrequently used, but critical skills.

Other types of simulation exercises can often be even more expensive, especially when they involve complex interactive computers in combination with mechanical mockups of human patients, aircraft cockpits, or other equipment. However, simpler paper and pencil simulations are often used for teaching and assessing proficiency in critical skills, especially those involving problem recognition, information gathering, and decisionmaking (Giffin (16)).

Paper and pencil simulations of this type have recently been developed for teaching coal miners how to cope with underground mine emergency situations (Cole (20-21) and Lacefield (22)). Knowledge gained from constructing and field testing these types of simulations can contribute directly to the design of effective role play simulation exercises. As McGuire (23) notes in a review of medical simulation research, it is not the format of problem presentation but the content and logic of the simulated problem that is basic to an effective exercise for testing proficiency in such skills. Simulations may take many formats including computer administration, paper and pencil exercises, gaming situations, full-scale drills and contests in the workplace, or structured classroom role playing activities. This paper deals with the latter type of simulations. However, the principles noted often apply to other types of simulation problems, including the latent image paper and pencil format exercises developed in this project and described in other reports (Cole (24)).

MINER EXPERIENCE WITH ROLE PLAY SIMULATIONS

If designed appropriately, role play simulations are motivating and effective means for teaching and assessing problem solving skills needed to cope with emergency situations. If they are not carefully designed, classroom role play simulation exercises fail to achieve their potential. Both well designed and poorly designed role play simulations have been experienced by most miners and trainers. The simulations experienced by most miners fall into three general categories: Mine rescue contest exercises, first aid contest exercises, and impromptu and less complete classroom role playing situations that are usually carried out in the context of teaching interpersonal dynamics. This generalization is based upon visiting and observing many of these types of training activities in the mining industry in 6 States over a 4-yr period.

Mine rescue training exercises are widely used in the mining industry. These are elaborate and detailed problem solving exercises that involve the use of actual mine rescue equipment and many props to simulate an underground mine environment. Sometimes the exercise is carried out underground in an actual mine. During the exercise some persons

SCENARIO

EMERGENCY RESPONSE TRAINING

DATE ____________ TIME ____________

NATURE OF EMERGENCY: Acid battery explosion

TRAINING TO BE UTILIZED/TESTED: First aid in acid environment

LOCATION OF EXERCISE: Emergency generator building

NOTIFICATIONS OR SPECIAL INSTRUCTIONS: Fire Department. Request that the fire department take information from the plant emergency response team and advise that no ambulance is available for transport of injured.

DESCRIPTION OF INCIDENT: A maintenance man is checking the bearings on the emergency generator. Batteries are being charged. Upon completion of his job, he lights a cigarette. The flame ignites hydrogen which is trapped in the area because of a ventilation problem.

The battery explodes.

The man is hit by flying debris.

His head is cut.

His hand is burned by the exploding hydrogen gas.

He is covered with acid.

PROCEED AS IF THIS SITUATION WERE AN ACTUAL EMERGENCY.

FIGURE 1.—Example of realistic simulation exercise (Olsen (*19*)).

play the role of injured or trapped miners while others adopt the multiple roles of the mine rescue team and its support staff. The exercise is structured around a complex and realistic problem, such as a mine fire or explosion. The simulated victims and the mine rescue team do not know all of the problem structure as the exercise begins. Rather, they know only the information that would typically be available to them in a similar actual mine emergency. Thus, as in real life, details of the problem become known to the role players only as they develop a plan, enter the simulated mine and attempt to locate and rescue the missing miners.

The problem unfolds and changes as the rescue team explores the mine, gathers information, encounters barriers and hazards, and modifies strategy to achieve the goals of locating and evacuating trapped and/or injured miners and restoring the mine to a safe condition. Although there are well-established procedures and protocols for mine rescue work, every mine exercise is a different problem. A good solution (rescue) requires a flexible and unique combination of prior knowledge and skills. The development and execution of constantly changing plans and strategies is required. Standard protocols must be recalled and applied when appropriate. As the rescue proceeds, inferences must be constructed about mine conditions based on available information. A good solution creatively integrates the large amount of information and the many procedures basic to any problem. Miners and trainers enjoy these elaborate simulations and learn much from them.

First aid exercises and contests are also widely used in the mining industry, often in conjunction with mine rescue contests. These exercises also involve miners who role play injured accident victims and others who adopt the roles of a first aid team. The simulated injuries are usually severe. First aid kits and supplies normally available in mines are available to the first aid team. However, unlike mine rescue exercises that require problem solving activity, most mine first aid exercises and contests place less emphasis upon initial problem identification and formulation. The nature and extent of the victim's injuries are usually given to the first-aiders, often printed on a piece of paper. The exercise usually focuses upon the skill of the first aid team in applying standard procedures to stop bleeding, dress and bandage wounds, splint and bandage fractures, and immobilize the victim on a stretcher. These types of exercises present the first-aiders with an already well-defined problem. The emphasis (and scoring) is upon the rapid and skillful application of first aid procedures according to standard protocols. The early and crucial information gathering, problem formulation, and strategy development aspects of the problem are ignored. These include (1) the first-aider's initial evaluation of the accident scene to determine if it is safe to treat the victim, or if some other action(s) must be taken first; (2) the approach to and removal of the victim, once the mine area in which the victim is located is judged safe for the first-aiders to enter; (3) the evaluation of the victim's injuries through a detailed primary and secondary survey; (4) the use of information from the primary and secondary surveys to construct inferences about what injuries are present, which should be treated, in what order, and by what methods; (5) the planning and implementation of complex details of communicating with surface personnel and transporting the victim to the portal.

The third type of role play simulations with which many trainers and miners are familiar are designed for inclusion in annual refresher training and similar classroom settings. Constraints of time and location generally require these simulation exercises to be brief, perhaps no longer than 20 min, and to not require elaborate props or equipment. Often the content of these role play simulations concerns interpersonal dynamics among miners and their supervisors. Sometimes the content is technical, such as the role playing of a mine inspector and a mine supervisor conversation about a list of violations found by the inspector in a current visit to the mine. If carefully planned, developed, and introduced at the appropriate time and in an appropriate manner, these types of shorter simulations can also be engaging and elicit the full participation of miners. However, even short classroom simulation exercises are more difficult to design and structure than they may at first appear.

It has been observed that many mine trainers have tried to use role play simulations like these in their classes, but with poor results. Often there is too little planning and preparation on the part of the instructor. Skillful and experienced instructors who can use impromptu role play situations effectively tend to be few and far between. Frequently the method fails to achieve its potential because the trainer fails to select and structure an authentic problem that challenges participants present levels of knowledge and skill. Oftentimes the problem structure is not clear to the trainer or to the miners. The content and logic of the problem is often not well articulated. The roles of the players are often not specified clearly, and class members feel uncertain and uneasy about what they are to do. Sometimes, little thought is given to what the members of the class who are not involved in the role play situation are to do during the activity. Usually there are no objective criteria for evaluation of the role play performance. Following the activity, it is easy for the persons who observed to be critical of the actors. Thus, the role players may feel uneasy and defensive. One or two experiences with role play simulations like these serve to disenchant both miners and trainers. In the future, both will tend to avoid similar classroom simulation exercises or activities that they perceive as similar to these simulations.

Much preparation prior to the simulation is necessary if the instructor is to present the simulated problem in a realistic and time efficient manner, and if trainees are to become fully and quickly engaged in the activity. Effective role play simulation exercises incorporate a number of components. These include (1) simple props that simulate key aspects of the problem setting, (2) carefully chosen graphics and illustrations that help describe the problem, (3) a brief written description that clearly presents the initial problem, (4) brief and clear instructions to the individual class members who play various roles in the simulation (and to those who observe the role play simulation), and (5) a means to evaluate specific aspects of the problem solving performance of the participants. Role play simulations that are usually designed and used by classroom instructors tend to be more impromptu and less complete with respect to these design criteria.

First aid classroom role play simulations that meet good design criteria and that are known to be motivating and effective instructional tools have been developed and researched with college student populations at the Ohio State University (Gilbert (1)). This earlier research was used to design the first aid simulation exercises discussed in this paper.

GILBERT FIRST AID SIMULATION TECHNIQUE

In his dissertation, Gilbert (1) set out to develop an inexpensive, easy to use, and effective simulation method for teaching basic first aid skills. His review of the earlier research categorized simulation exercises into eight different approaches. Many of these approaches, such as computerized mechanical models of injured human victims, full-scale field simulations of accidents with injury makeup kits and human actors (as often used in the military), and complex flight or other equipment simulators are not available to instructors in typical first aid courses. Other methods, such as those described by Olsen (19) using human actors with animal blood and entrails to simulate industrial accidents at actual work stations, are difficult to stage, very time consuming, and fraught with potential ethical and legal problems.

Using ideas and techniques from simulation methods and research across the eight approaches, Gilbert developed an inexpensive, simple, but effective simulation approach. The procedure provides short verbal descriptions of the problem situation, brief written instructions for human actors (victims and bystanders) in brief role playing situations, injury tags placed on the victim, and a performance scoring sheet. The simulation is presented to the trainee as if he or she had suddenly encountered an accident victim.

The trainee must first gather information from the victim and bystanders, by observation and questioning. Information about the nature and extent of injury to the victim is partially revealed by the trainee's primary and secondary surveys of the victim. Bleeding, puncture wounds, dislocations, fractures, and other injuries are not fully simulated with makeup kits. However, they are simulated by the victim actor and by injury tags placed on the victim's body at appropriate places; e.g., a small label stuck to the patient's ear that says "small amount of clear, slightly yellow fluid running out of ear," a small label on the upper left chest that says "puncture wound (about the size of a pencil) making a sucking noise," or a large red card on a limb or the floor that says, "large pool of dark red blood and blood-soaked clothing."[6]

The size, location, and prominence of the injury tag is related to the size, location, and prominence of actual injury cues on real victims with the types of injuries being simulated.

To perform effectively, the trainee must find and make use of all the cues (position of victim, bystanders observations, injury card cues located on the victim, etc.). He or she must then decide upon a course of action and administer first aid. For each simulation exercise there is a performance check list that is used by the instructor to score the proficiency of the trainee. An example of a Gilbert simulation exercise and a performance scoring sheet is given in figures 2 and 3, respectively.

Gilbert tested his simulation method in a large experimental study with college students. He found the method to be highly motivating to students, inexpensive, and effective in teaching basic first aid skills as outlined in the "First Aid and Personal Safety Course of the American Red Cross" (25). He also found his method was effective in measuring student knowledge of first aid skills as validated by the "Ohio State University First Aid and Personal Safety Achievement Test" (Gilbert (1)). The Ohio State test is a standardized 100 item multiple choice test. More recently Gilbert (2) has further refined and validated his simulation method with other samples of persons and with the "Burkes Emergency Care Knowledge Test" (Burkes (26)).

From his research, Gilbert concluded that persons trained in the method were able to learn to perform procedures correctly and that they achieved mastery of verbal knowledge about first aid procedures. However, his study did not determine how long trainees retained this proficiency and knowledge, or how well this procedural proficiency in first aid generalized to actual first aid practice.

[6] These injury labels are similar to the labels used in surface simulations of mine rescue contests where printed material on cards placed on the ground or simulated rib disclose information to the team as it advances (water, methane level, roof fall, etc.).

Situation #7B: Industrial Accident

Situation:

You are working on a construction project when there is a cave-in and material strikes a co-worker.

Where:

Ground level of a new building project

Miscellaneous Information:

You fear the building will continue to cave in.

Position of Victim:

On back

Special Instructions for Victim:

You are Unconscious and remain so.

Supplied Materials:

1. Assorted bandaging materials
2. Coat

Tags:

1. Moderate bleeding (1)-front of scalp
2. Mild bleeding (1)-nose
3. Mild bleeding (1)-back of neck
4. Moderate bleeding (1)-front of left lower leg

FIGURE 2.—Example of Gilbert simulation exercise.

Name of First Aider ______________________ Grader ______________________

Situation #7B: Industrial Accident

	Yes Well Done	Yes Adequate	No
1. Was the victim removed from the dangerous area in proper fashion?	3,2	1	0
2. Was the victim properly examined for all injuries?	2	1	0
3. Was moderate bleeding of leg controlled and bandaged properly? A. Direct pressure and elevation (1) B. Pressure point (1) C. Proper bandage and dressing (2)	4,3	2,1	0
4. Was moderate bleeding of scalp controlled by a loose bandage and dressed so as not to stop flow completely?	4,3	2,1	0
5. Was concussion suspected and victim thus handled very carefully?	2	1	0
6. Was mild bleeding of neck controlled and bandaged properly? A. Direct pressure (1) B. Proper bandage and dressing-non-circular (2)	3,2	1	0
7. Was mild bleeding of nose controlled in an appropriate fashion?	2	1	0
8. Was victim treated for shock? (In this case elevation of feet is inappropriate and elevation of upper body is acceptable.)	2	1	0

Comments:

Add ______________________

Deductions ______________________

Total ______________________

Possible 22

FIGURE 3.—Example of Gilbert simulation exercise performance scoring sheet.

POTENTIAL OF GILBERT SIMULATION METHOD FOR MINER TRAINING

Prior to the work of this project, it appeared that the Gilbert method for teaching and assessing proficiency in first aid skills had not been applied to miner training. However, for a number of reasons, the method was judged to have promise for teaching first aid skills to miners in annual refresher classes.

First, it is relatively easy to develop and use simulation exercises patterned after the Gilbert method. Neither the development of the exercises nor their use requires any special equipment beyond that typically available to annual refresher class instructors.

Second, the method is adaptable. Where miners might be inhibited about doing a full body survey in a suspected spinal injury victim (including checking for penile erection and toe flexure), a manikin rather than a human actor might be substituted.

Third, the method is brief and time efficient. A single simulation can be completed, evaluated, and critiqued in a 20- or 30-min period. Multiple role play simulations of the same or different problems may be undertaken with small groups of trainees in the same classroom, thus involving all participants in hands-on skill building activities.

Fourth, the Gilbert method has proven to engage the full attention and participation of college students and others in learning first aid skills, and it has also been shown to increase their first aid knowledge and skills.

Fifth, many of the simulation exercises developed by Gilbert and his colleagues may be easily adapted to first aid problems that are common in underground mines.

Sixth, the method can be used to present realistic problems that mimic well the full range of problem solving activity required in actual mine first aid emergencies, much more so than first aid team contest exercises, or refresher class first aid instruction that presents a well-defined first aid injury case and focuses mainly on performance of first aid procedures.

Seventh, field interviews revealed that miner first aid skills and knowledge were weakest in critical information gathering, judgment, and decisionmaking. These specific skill areas are emphasized by the Gilbert simulation method.

For these reasons the Gilbert simulation method was studied and adapted to the production of classroom simulation exercises for use in annual refresher training.

MINER FIRST AID STRENGTHS AND WEAKNESSES

A study of miner performance of first aid skills as practiced on injured fellow miners was undertaken (Cole, (21)). Medical personnel and miners trained as emergency medical technicians (EMT's) were sampled from four coal-producing regions in Kentucky, West Virginia, and Virginia. The sample included those first aid experts who first see and treat injured miners who have earlier received first aid from their fellow miners. The observations of these experts were gathered from interviews. Interviewers used critical incident and structured interview forms designed to elicit from these experts their direct observations of what first aid tasks miners usually perform well and what tasks they often perform poorly. One hundred twenty first aid experts were interviewed, some in group settings. Reports from 77 experts who made individual responses were collected and tallied. Table 1 describes the geographic distribution and the types of experts involved in this sample. In the interviews it was made clear that the expert's frame of reference should be the strengths and weaknesses of miner actual first aid performance. The quality of performance was to be judged by the expert's examinations of the victims, following initial first aid treatment by non-EMT trained miners.

The working EMT's shown in table 1 included five underground coal miners who routinely are called to the scene of underground first aid emergencies, and seven EMT ambulance personnel who routinely meet injured miners at the portal. The 33 EMT miner trainees are all experienced miners, many of them supervisors, who had nearly completed

TABLE 1. - Types of first aid experts interviewed and their geographic distribution

Expert type	Eastern KY	Western KY	Central WV	Southwest VA	Total
Emergency MD	1	0	2	4	7
Emergency room RN	2	3	3	5	13
EMT instructors	6	1	0	1	8
Working EMT's	0	13	1	0	14
EMT miner trainees	16	17	0	0	33
Other	2	0	0	0	2
Totals	27	34	6	10	77

16 weeks of EMT training but who had not yet passed the certification examination.

The experts interviewed reported miners were strongest in following standard procedures for treating obvious injuries, especially splinting and bandaging simple fractures, caring for cuts, abrasions, and sprains, and controlling bleeding. Miners were reported as most often making serious errors when (1) immobilizing and transporting victims with back and neck (spinal) injuries, (2) dressing and immobilizing compound fractures, (3) rushing to move an injured miner without first immobilizing and stabilizing the victim, and (4) failing to do a victim evaluation through a primary and secondary survey.

Poor performance on these tasks was reported to be caused primarily by failure to discover hidden or nonobvious injuries. Missing hidden injuries was said to result from miner failure to conduct an adequate initial hands-on patient evaluation. Thus, the victim's injuries, unless obvious, tend to remain unidentified. Properly evaluating the victim for injuries tends to improve first aid care because hidden injuries may be found and treatment priorities established.

Analysis of the data suggested there is a consensus among the experts on both first aid treatments performed well and those performed poorly. Obvious injuries are generally treated well, hidden injuries and illnesses are not, with a major exception that obvious compound fractures are often not treated well because the treatment procedures are difficult.

Sometimes obvious and hidden injuries are combined in the same victim. Table 2 reports the experts' estimated percent of injuries miners treat well or poorly when the injuries are obvious, hidden, or combined. Table 3 shows there is a strong positive correlation between those first aid treatments miners do well-poorly and the obvious-hidden nature of the injury. The observed correlation between these two dimensions is 0.53. When the obvious but difficult to treat injuries (compound fractures and amputations) are omitted from the obvious-done poorly cell, the relationship is stronger and the correlation increases to 0.64.

What differentiates miner treatment of obvious and hidden injuries? It appears that treatment of obvious injuries requires knowledge of technique and appropriate use of first aid equipment, the skills that are emphasized in annual refresher first aid training and first aid contests. Appropriate treatment of hidden injuries or illnesses appears to require more emphasis upon gathering information, evaluating the accident scene and victim, constructing inferences about what the probable injuries are, and prioritizing first aid treatment and procedures.

TABLE 2. - Obvious, hidden, combined, and other injuries treated well-poorly

First aid	Obvious	Hidden	Combined	Other
Cases reported	117	41	43	9
Treated well.... pct	68	7	26	(1)
Treated poorly.. pct	32	93	74	(1)

[1] These frequencies were too small to compute meaningful percentages.

Interviews with the 120 experts also yielded other information, including a consensus that miners often failed to communicate clearly and effectively with each other and with surface personnel when they are involved in a first aid emergency. Lack of clarity in communication, or failure to communicate the details of an injury accident can have severe consequences for a victim. Examples cited include (1) a mantrip bringing out an injured miner being forced to wait for the track to be cleared of other equipment, when an appropriate call earlier could have cleared the track all the way out, (2) an injured miner who had been brought 4 miles to an elevator and had to be transported back in the same direction from which he had started, plus an additional 4 miles, to another elevator because the first elevator was temporarily inoperative while being repaired, and (3) getting an injured

TABLE 3. - Relationship between first aid done well-poorly and obvious-hidden injuries (Reported frequencies of well-poorly done first aid)

	Done well	Done poorly	Total
Including compound fractures and amputations:[1]			
Obvious	79	38	117
Hidden	3	38	41
Total	82	76	158
Excluding compound fractures and amputations:[2]			
Obvious	79	23	102
Hidden	3	38	41
Total	82	61	143

[1] Chi square = 44.09, 1 degree of freedom; P = <0.001; phi coefficient = 0.53.

[2] Chi square = 58.81, 1 degree of freedom; P = <0.001; phi coefficient = 0.64.

miner to the surface promptly and into the company ambulance but not being able to leave the mine property for the hospital because the very long surface unit train was blocking the single roadway to the mine.

After the field interviews of the 120 first aid experts from the underground coal mine industry were completed, a meeting at the National Mine Health and Safety Academy was convened with 13 additional experts familiar with medical emergencies in underground coal mines in six States. These experts, who routinely teach first aid as well as provide first aid and emergency medical treatment to miners, were also asked to identify the most common and most serious errors made by miners in first aid treatment of fellow accident victims. The group members identified most serious and frequent errors as failure to do a careful injury assessment, failure to prepare and stabilize the victim prior to transport to the surface, and failure to monitor the victim during the transport period.

Miners were said to often act too quickly, moving the victim out without first searching for and identifying the extent and nature of injuries. More extensive injuries and complications frequently result for the victim because first-aiders fail to conduct critical injury evaluation, fail to find and care for serious injuries, and hurry transport. These 13 experts reviewed the findings from the field interviews and independently judged them to be valid. The results of the field interviews of first aid experts, and the independent observations of the 13 experts, are also consistent with an earlier set of findings and recommendations from a study concerned with the first aid needs and skills of miners (Pickar (27)).

In summary, good first aid in underground mine emergencies requires a broad problem solving focus, not only knowledge of specific first aid procedures. Good first aid simulations should be structured much like good mine rescue contest problems. They should present a simulation that mimics the complexity of problem identification, information gathering, decisionmaking, communication, strategy development, rapidly changing conditions and unknowns, and the application of specific first aid techniques required to administer effective first aid in actual mine emergencies. These research results from studies of miner needs for first aid training, and the practical knowledge gained from studies by Gilbert and his colleagues, contributed to the development of short and time efficient first aid simulations for use in annual refresher training classes. A sample exercise that resulted from this integration of research and practice is included as an appendix to this paper. It can serve as a model for others who are interested in developing additional first aid simulation exercises for miners.

NEW FIRST AID SIMULATIONS FOR MINER TRAINING

Many of the approximately 50 simulation exercises in the Gilbert (2) manual are relevant to underground coal mine first aid situations and can be used with little modification. (All of Gilbert's simulations are available for duplication without copyright restrictions.) Other Gilbert type simulations of coal mine medical emergencies can easily be developed from real past accident situations. The example simulation exercise and scoring sheet in figures 4 and 5 illustrate this. The graphic depiction of the accident situation (fig. 6) is taken from the MSHA "Coal - Underground Fatalities" (28). The problem situation, injury tags, and scoring sheet are designed for this case. Although the miner in the accident case was fatally injured, for purposes of the exercise, the miner's injuries are severe, but not necessarily fatal if he is given prompt and proper first aid care. Many other problem situations can be taken from the MSHA "Fatal Injury Abstracts and Illustrations" program, as well as from MSHA and State accident investigation reports. Consequently it is a relatively easy task to make up an array of Gilbert type simulations based on real case materials.

The first aid simulation exercise (fig. 4), and two others involving other mine injury first aid situations were distributed to a group of instructors who routinely teach annual refresher training classes. While these persons found the content of the exercises to be of interest, they were unsure about how effective the exercises might be in their classes and also unsure how to go about presenting the material. Some thought miners in their classes might be unwilling to participate in such an activity. Others thought the simulation would require too much preparation, or would be too difficult to carry out. Subsequent to these meetings, the Gilbert method was modified to make the exercise purpose more explicit, to make it easier for trainers and miners to use the simulations, and to produce a realistic simulation similar in many ways to the traditional mine rescue exercise simulations popular with miners and trainers.

Examination of the sample exercise in the appendix to this paper illustrates all the basic features of the Gilbert method have been retained, while additional design features have been added that make the simulation easier for miners and instructors to use.

The following is a list of the design guidelines for these newer role play simulations.

1. The problem should challenge participants present levels of first aid knowledge and skill. There should be an opportunity for the trainees to identify and solve problems, not only the opportunity to demonstrate first aid procedures such as giving artificial respiration or bandaging a wound.

2. The problem context should be authentic with respect to the trainees workplace experiences. The problem, the language used to describe it, the roles and relationships of the victim and role players, the graphic illustrations and the props

Situation #1: Roof Fall Injury

Situation:

A miner is hit by 12 inch thick, 4 x 5 foot kettle bottom while shoveling coal

Where:

48 inch coal near a continuous miner

Miscellaneous Information:

There are two other members in the crew and you are the most experienced. Nearest phone 5 minutes away. It is twenty minutes to portal by mantrip.

Position of Victim:

Lying on side under part of broken kettle bottom

Special Instructions for Victim:

You can talk but are dazed and cannot move your arms and legs.

Special Instructions for Crew Members:

Act excited but do what you are told.

Supplied Materials:

Mine first aid kit and stretcher (5 minutes away).

Tags:

1. Part of kettle bottom on top of miner (Simulate with cardboard box or other similar object)
2. Left upper chest pulls in when miner breathes in. (Apply label to left chest under shirt)
3. Bones of upper spine are out of line. (Apply label to upper spine under shirt)

FIGURE 4.—Sample Gilbert-type exercise simulation modeled after a coal mine accident.

Name ______________________	Grader ______________________

Situation #1: Roof Fall Injury

	Yes Well Done	Yes Adequate	No
1. Was the kettle bottom promptly, gently, and properly removed from the victim?	3	0	0
2. Was the victim properly examined and questioned for all injuries?	2	1	0
3. Was the victim not moved unnecessarily?	3	2	0
4. Was the victim given verbal encouragement?	2	1	0
5. Was crushed chest properly diagnosed and splinted?	2	1	0
6. Was possible spinal injury properly diagnosed and victim handled correctly?	3	2	0
7. Was victim treated for shock?	2	1	0
8. Was help sent for?	1	1	0
9. Was victim properly immobilized and moved properly?	3	2	0

Add ______________________

Deductions ______________________

Total ______________________

Possible ______ 21 ______

FIGURE 5.—Sample Gilbert type exercise simulation performance scoring sheet for roof fall accident situation.

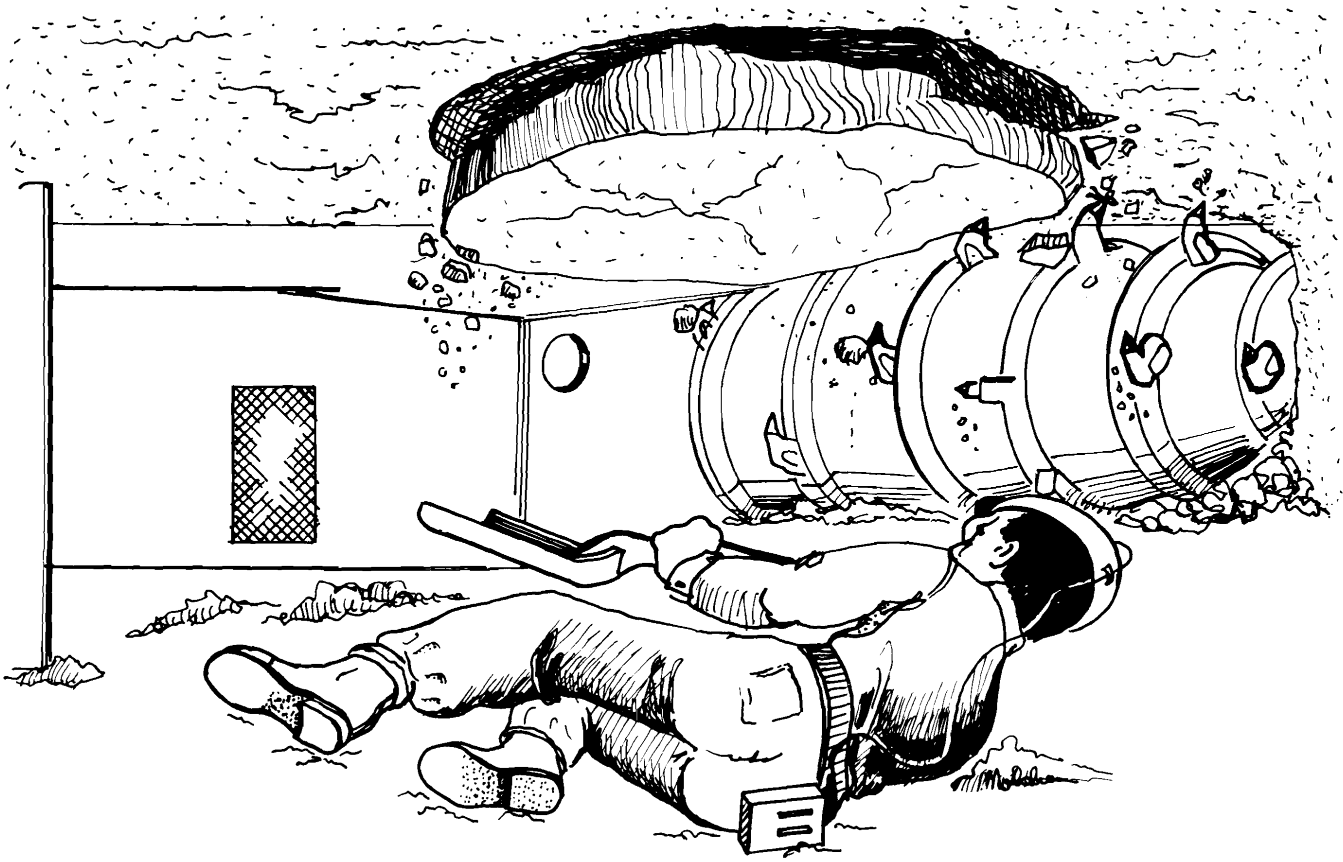

FIGURE 6.—Depiction of roof fall accident situation (*28*).

used to help present the problem, the types of injuries simulated, as well as their cause, must all be seen as authentic and realistic by the trainees with respect to their workplace experiences.

3. The initial problem situation, descriptions of additional background information, and instructions to the role players, should all be brief and articulate statements written in simple language. Drawings, diagrams, graphics, and simple props should be used along with verbal descriptions to present the main aspects of the problem and its context.

4. The initial problem situation needs to be described adequately. Relevant background information that would be known to the persons in an actual problem situation should be briefly presented. However, only that information that would be immediately available to the first-aiders from the emergency scene itself, from the victim or witnesses, should be available in the initial problem narrative statement. Otherwise, the simulation does not provide the opportunity for the trainee to identify the problem(s), establish treatment priorities, and select and apply relevant first aid procedures.

5. The simulation exercise should be designed to reveal additional information to the problem solvers role playing the first-aiders as the simulation unfolds. The instructions to the victim, the placement of injury and accident scene cues, and all other aspects of the problem should be designed to release additional relevant information to the problem solvers as appropriate inquiries are made as the problem is worked.

6. Simple props that simulate the key elements of the accident scene, the injuries to the victim, the materials and resources at hand, and any special conditions in the specific accident situation need to be developed and presented throughout the exercise as the problem unfolds. These props can include simple drawings and diagrams of the accident scene including the location and appearance of equipment and the victim, depictions of obvious and hidden injuries through the appropriate placement of injury tags and simulated injuries, special instructions to the victim about how he or she should act or speak, as well as collections of equipment and materials that would usually be available at or near to the accident scene, e.g., other persons, telephones, first aid kits, jackets, tools, etc.

7. The brief printed instructions to those class members who are to role play the victim(s), witnesses, and/or the first-aiders need to be prepared on separate cards and presented to the role players when the simulation is introduced. Similar sets of brief instructions need to be prepared and given to trainees who are not involved as actors but will observe the simulation. Prior to the simulation, each group of trainees, victim, first-aiders, and observers need their own set of instructions to define their role in the activity.

8. A performance evaluation sheet by which to rate the effectiveness of the first aid treatment administered to the victim by the first-aiders should be prepared. All the key steps in proper first aid treatment for the case in the simulation should be listed and followed by a short and easy to use rating scale. Following the simulation, all the members of the class including the instructor, the victim, the first-aiders, and the observers should rate the first aid performance on the rating scale. Discussion of the ratings awarded by the instructor and the class members should be used as aids for correcting errors, reinforcing correct performance, and illustrating first aid concepts, procedures, and techniques.

In addition to the materials to be used with the miners in the classroom, a carefully designed instructor's guide should be prepared for the trainer. The following is a list of design guidelines for the instructor's guide:

1. The instructor's guide should present the problem situation in a brief narrative and graphic form that will also be used to help present the problem situation to the miners. This helps the instructor to grasp quickly the content and context of the problem. (See pages 3-5 of appendix.)

2. The instructor's guide should describe in a clear and logical manner what the instructor must do before the simulation to prepare for class, what he or she must do during the simulation to ensure an effective session, and what must be done after the simulation to help class members profit from the exercise. This type of detail in the instructor's guide makes it easy for the instructor to prepare for class. Uncertainty about how to proceed is avoided. Detailed prior preparation and planning is assisted by such directions. (See pages 6-10 of appendix.)

3. The instructor's guide should be designed so that everything the instructor needs to prepare for and carry out the simulation is provided. This includes the narrative description and graphics used to present the problem situation to the miners (prepared in large type suitable for copying to readily visible overhead transparencies); injury tags, instructions to the victim, first-aiders, and observers all printed neatly on cutout cards that may be quickly clipped out and used as is; the performance rating form; additional diagrams, charts, and pictures to be used following the simulation; suggestions about how to adapt, modify, and enhance the exercise; etc. Those props and materials that cannot be included in the instructor's guide should be commonly and easily available in typical annual refresher training classes. These things include first aid kits, blankets, jackets, tools, and objects like desks and tables used to simulate equipment like roof bolters, continuous mining machines, and such things as rolled up newspapers taped with masking tape to simulate an amputated arm.

4. The instructor's guide and the simulation activity itself should both be designed such that once the instructor prepares for one class, he or she can save the props and materials and use them again to teach other classes for the same simulation, with minimum new preparation time.

5. The instructor's guide and the simulation activity itself should be designed to help instructors generalize these instructional design principles to the planning, development,

and use of other effective simulation exercises generated by instructors themselves.

There are two primary instructional design differences between the Gilbert simulations and these newer first aid simulations. First, with the new method the presentation of the problem scenario is more detailed and complete, but still short and time efficient. In the Gilbert method, the problem presentation is accomplished through brief verbal statements and descriptions along with the physical role playing presentation of the accident scene complete with the role playing victim and injury tags. (See figure 1.) In the new method the problem situation is presented in more detail. A one-page, large-type description of the problem and its background features is presented on an overhead transparency. (See page 3 of appendix.) In addition, detailed drawings and graphics are presented on overhead projector transparencies. (See pages 4-5 of appendix.) These diagrams and drawings quickly convey details of the accident scene that would normally be available in an actual emergency, but that are difficult to describe in verbal statements. It is also easy for the instructor to set up the simulated accident scene with reference to the written and graphic depiction of the problem. This simultaneous multiple presentation of the problem through verbal, graphic, and physical simulation of the accident scene and injuries helps make the exercise more realistic and meaningful to the miners who enter the classroom in the role of first-aiders or observers.

A second instructional design difference between the Gilbert simulations and the newer method concerns the degree to which the instructor is provided details and assistance in preparing for and carrying out the classroom simulation activity. In typical Gilbert simulation exercises the instructor is provided with little specific information about how to prepare for the simulation, conduct the activity, or engage in fruitful followup discussion. (See figure 1.) The new method makes these matters explicit. Consequently, instructors who are not skilled in using classroom role play simulations as an instructional method may be expected to do a better job of preparing for and conducting their class. Examination of the instructor's guide for the sample simulation exercise included in the appendix illustrates the explicit nature of the assistance to the instructor in planning and conducting the exercise.

First, the guide presents the problem situation to the instructor in verbal and graphic form. (See pages 3-5 of appendix.) Thus, the instructor immediately knows what the problem is and has information about how the accident scene must be simulated.

Second, the instructor is told how to prepare for the simulation using the materials in the instructor's guide and locally available resources. Specific suggestions include a list of materials and props that must be gathered prior to the simulation, details of how to stage the simulated accident scene, how to recruit the role players, and how to present the role players and the observers their individual tasks and instructions. (See pages 6-8 of appendix.) Additional directions are provided that explain what the instructor should do during the simulation, and how to conduct an effective corrective feedback and discussion session after the simulation including using the performance evaluation ratings by all class members, victim, first-aiders, and observers. (See pages 9-10 of appendix.) Tips are also provided concerning how long the exercise will take, how to save the injury tags and props to make teaching subsequent classes with the same simulation exercise an easy task, and how to adapt and modify the exercise to local situations and needs. (See pages 10-11 of appendix.)

Third, the guide provides the instructor with many of the materials he or she needs to conduct the simulation. A set of performance objectives that define what the class members are to learn and do is helpful to instructors in clarifying their own thinking about the activity and may be used to report to superiors the purpose and content of the activity. (See page 13 of appendix.) Ready to use materials needed for the simulation are provided. These include the performance rating form (see pages 14-15 of appendix), a trainee questionnaire that allows the miners to evaluate the exercise (see page 16 of appendix), and a similar instructor's evaluative questionnaire. The instructor need only duplicate these materials.

In addition, the instructions to the victim and the first aid role players, the injury tags, and prop tags are all prepared in final form and sufficient number (see pages 17-20 of appendix.) Again, the instructor need only make one copy of these, cut out the tags, and mount them on a card. Once this is done the same tags can be used repeatedly in new classes with the same simulation activity. Additional diagrams and drawings are included that may be useful to the instructor when discussing the problem and providing corrective feedback after the simulation. These need only be copied to overhead transparencies to be used by the instructor (see pages 21-23 of appendix.) Finally, the reference sources are provided for the first aid techniques and procedures used in the simulation problem (see page 24 of appendix).

Earlier observations and studies suggested that mine health and safety trainers are quite competent in the technical aspects of what they teach, but less informed about how to design and use effective classroom simulations. An additional important design characteristic of these newer simulation exercises is their capability to teach instructors how to plan and conduct classroom simulations. Once an instructor has used one or two simulation exercises like the one in the appendix to this paper, he or she should learn specific techniques that may be applied to the development and use of similar simulations for annual refresher training classes. The instructor's guide is deliberately designed to serve as a model to which instructors can refer as they develop, plan, and carry out their own simulation exercises for annual refresher training classes.

FIELD TESTING AND NEW SIMULATION EXERCISES

The sample simulation exercise in the appendix to this paper has been field tested in 3 States at 6 training sites. To date, data from 3 classes at 3 sites in 2 States have been collected and analyzed. Additional field tests of this exercise and other first aid simulation exercises are in progress.

The basic characteristics of the miners involved in the field test for which these results are reported are described in table 4. Although there were 59 miners involved in these three classes, the variable number of persons reported in table 4 and later tables reflects missing data in specific categories. Table 5 describes the three classes for which these data are reported. The number of first-aiders is the number of persons who role played the first aid care givers. The first class had four first-aiders, two of whom are State mine inspectors with mine foreman certification, a mine equipment sales representative with advanced first aid training, and an engineering technician. The five first-aiders in the second class included three mine health and safety instructors (two with advanced training in first aid and who routinely teach first aid), one mine supervisor, and one miner. The three first-aiders in the third class included two miners with only the usual training in first aid, and a mine supervisor with advanced first aid training. None of the first-aid role players were trained or certified as EMT's. Observers from the University of Kentucky were present in the first and second classrooms.

The data gathered from these three classes were analyzed and used to report two basic types of findings. These are (1) miner evaluation of simulation exercise based upon the pooled ratings by all class members on specific criteria (see the trainee's questionnaire, page 16 of appendix), and (2) miner performance ratings of the first aid skills of the three groups of persons who role played the first-aiders in each classroom.

TABLE 4.-Characteristics of the three-site, three-class field test sample for a first aid simulation exercise

(56 male miners—mean age, 36.4 yr; mean experience, 8.3 yr)

	Number	Frequency, pct
Job classification:[1]		
Miner.	28	51.8
Maintenance-technical.	12	22.2
Supervisory-management.	13	24.1
Other.	1	1.9

	Training	Certification	Performance
Category, pct:[2]			
Supervisor	17.9	16.1	1.8
Mine safety committee	3.6	8.9	1.8
Mine rescue	5.4	3.6	1.8
CPR	17.9	26.8	12.5
Advanced first aid.	25.0	10.7	8.9
EMT	7.1	12.5	1.8
Advanced life support	7.1	3.6	0.0
Other	3.6	7.1	5.4

[1]Information not provided by 2 class members.
[2]Frequency of self-reported level of expertise.

TABLE 5. - Class size and number and qualifications of first-aiders at three sites

	Number of first-aiders and qualifications	Observer present
Class 1, 18 persons	4—2 State mine inspectors, 1 sales representative with AFAT, 1 engineering technician.	Yes
Class 2, 7 persons	5—3 instructors, 2 with AFAT, 1 mine supervisor, 1 miner.	Yes
Class 3, 31 persons	3—2 miners, 1 mine supervisor with AFAT.	No

(AFAT - self-reported advanced first aid training.)

MINER EVALUATION OF THE SIMULATION EXERCISE

The results of miner evaluations of the exercise are presented in table 6. All the miners reported the exercise content to be authentic and realistic. Over 98 pct reported the exercise would help them remember important first aid knowledge in the future. Over 87 pct reported they learned something new from the simulation. About 35 pct thought the exercise was too long, but over 92 pct reported they liked working the exercise. Approximately 94 pct of the miners felt the instructor's directions were clear and 96 pct felt that the exercise directions were clear. Approximately 93 pct judged the graphics as easy to understand and 89 pct found the exercise performance scoring procedures to be easily understood.

The results in table 6 and observations by project members in two of the classes indicate that both miners and instructors were able to use the simulation effectively. Miners were willing and able to carry out their role play assignments. Both the miners and instructors were able to execute all aspects of the activity as planned in the printed instructor's guide. Both the miners and instructors were able and willing to use the performance evaluation form properly as a positive teaching tool.

TABLE 6. - Miner ratings of exercise validity, relevance, quality, and utility (n = 59)

Content	Definitely	yes	Definitely	no	Mean	S.D.
	4	3	2	1		
Problem could happen	94.4	5.6	0.0	0.0	3.94	0.23
Help remember important things.	78.2	20.0	1.8	.0	3.76	.47
Learned something new.	60.0	27.3	10.9	1.8	3.46	.77
Exercise too long.	14.8	20.4	13.0	51.9	1.98	1.16
Liked working the exercise	67.3	25.0	7.7	.0	3.60	.63
Instructor directions clear	72.7	21.8	5.5	.0	3.67	.58
Written exercise directions clear	59.3	37.0	3.7	.0	3.56	.57
Graphics easy to understand.	58.2	34.5	5.5	1.8	3.49	.69
Scoring easy to understand	67.3	21.8	3.6	7.3	3.49	.88

MINER FIRST AID PERFORMANCE ON THE SIMULATION EXERCISE

The analyses that follow are based on the performance of the first-aiders in each class. Fifteen aspects of first-aider performance were rated on a common rating form. Each of the 15 scales on the form was designed to evaluate key aspects of rescue and first aid procedures needed to cope with the simulation problem. The problem involved a miner whose legs were crushed by a roof fall after he went under unsupported top to mark up the bolt pattern for the roof bolter. A proper performance requires the first-aiders to assess the accident scene, support the top, remove the rock from the injured miner, and rapidly move the miner out of this dangerous area. Only then is it appropriate to evaluate the victim for injuries, communicate with the surface, provide first aid care, and prepare to transport the victim to the surface. The problem and the performance rating form are described in the appendix to this paper. All members of the class, including the victim, the first-aiders, the observers, and the instructor rated first-aider performance on the form.

The performance rating form was found to be a reliable measure. Table 7 presents the internal consistency reliability estimates of the form for the miners from all three classes and with the miners from all three classes pooled. Thirteen of the fifteen scales on the performance rating form were significantly and positively correlated with the total score on the form. Items 9 and 10 (sending for help and communicating clearly to the surface) were not significantly correlated with the total performance rating score.

TABLE 7. - Internal consistency reliability estimates of the performance rating form

	Complete ratings[1]	First-aiders	Generalizability coefficient (alpha)[2]
Class 1	16	4	0.69
Class 2	7	5	.64
Class 3	26	3	.77
Classes pooled.	49	12	.80

[1]Only those rating forms that contained a complete set of ratings on all 15 questions were included.

[2]An estimate of the internal consistency or reliability of the scale. The maximum possible value is 1 and the minimum value is 0.

Comparison of the within classes and between classes sums of squares revealed that 52 pct of the variance in performance scores among the three classes can be attributed to differences in first-aider performance in the three classes. The remaining 48 pct of the observed variance in performance scores is attributed to variations in miner individual ratings of the same observed performance.

The performance rating total score for the first-aiders in each class was summed across the 15 scales for each rater. The average rating was then computed for each group (class) of first-aiders. Large significant differences were observed in the total performance scores earned by the first-aiders in each class (F = 24.80; df = 2.46; p = less than 0.0001). These results are reported in table 8.

The difficulty of each part of the first aid performance required by the simulation may be estimated from the raw scores of the 15 individual scales found on the performance rating form. Table 9 presents a description of the performance content of each scale on the rating form along with the maximum score for that scale, the mean score observed, and the standard deviation. These data are pooled across all three classes from a total of 49 ratings for the 12 role players.

Table 10 presents the same data, but broken down for each of the three classes. The large significant differences in observed total scores for the three classes are reflected in the differences in raw scores on the individual scale items.

TABLE 8. - Mean scores and standard deviations of total performance score by class

	Complete ratings	First-aiders	Mean score	S.D.
Class 1	16	4	55.34	11.15
Class 2	7	5	73.52	13.09
Class 3	26	3	35.37	15.45

[1]Total raw scores were converted to a scaled 0 to 100 score.

TABLE 9. - Difficulty for each of 15 rescue and first aid performance tasks[1]

Scale and performance dimension	Raw score statistics			
	Max	Min	Mean	S.D.
1.Support mine roof before entering face area	3	0	1.39	1.40
2.Safely remove draw slate from victim.	2	0	1.12	.99
3.Properly remove victim from under slate	3	0	2.16	1.14
4.Verbally encourage victim	2	0	1.08	.73
5.Promptly rescue-drag victim under good top.	3	0	2.45	1.00
6.Handle victim properly when rescue dragging	3	0	1.57	1.15
7.Conduct primary and secondary survey.	3	0	.55	.79
8.Find and treat both leg injuries.	3	0	.47	.87
9.Send for help promptly and properly	2	0	1.67	.55
10.Communicate clearly and accurately to the surface.	2	0	1.08	.76
11.Properly position and lift victim to stretcher.	3	0	1.35	1.13
12.Properly immobilize victim on back on stretcher.	3	0	1.02	1.11
13.Examine and treat victim for shock.	3	0	1.33	1.20
14.Maintain unconscious victim's airway.	3	0	1.27	1.29
15.Organize overall first aid and rescue efforts well and efficiently	3	0	.90	.85

[1]Performance data are raw scores for 3 first aid teams rated by 49 miners on all 15 performance items.

INTERPRETATION OF MINER PERFORMANCE SCORES

Four features of the performance results stand out: (1) The total performance scores are low for all groups, (2) all groups did an adequate job on only two scales, (3) the worst performance of the first-aiders was in conducting the victim evaluation and treating hidden injuries, and (4) large differences exist in the performance scores of the first-aiders in the three classes.

The overall scores are low for each group of first-aiders. (See table 8.) When the same exercise is given as a latent image test, miner scores are typically higher. The role play simulation version of the exercise requires miners to problem solve with less guidance than is offered in the latent image version of the exercise, which provides corrective feedback revealed through the latent image answers as the exercise is worked. Thus, miners learn and correct first aid procedural errors as they work the latent image exercise. In the role play simulation exercise, just as in real life, there is no corrective feedback, beyond that available from others present. If the

TABLE 10. - Differences in difficulty of 15 performance tasks by first aid group (class)[1]

Item[2] no.	Class 1 Mean	Class 1 S.D.	Class 2 Mean	Class 2 S.D.	Class 3 Mean	Class 3 S.D.	Significance, p less than
1.	3.00	0.00	1.57	0.98	0.34	0.85	0.0001
2.	1.94	.25	1.71	.76	.46	.86	.0001
3.	2.88	.50	2.43	.98	1.65	1.23	.0012
4.	.69	.70	1.86	.38	1.12	.65	.0028
5.	2.44	1.03	2.71	.76	2.38	1.06	.6496
6.	1.88	1.20	2.14	1.07	1.23	1.07	.1448
7.	.31	.48	1.43	1.13	.46	.71	.0538
8.	.31	.48	1.00	1.41	.42	.86	.0319
9.	1.50	.63	1.86	.38	1.73	.53	.1259
10.	.69	.60	1.00	1.00	1.35	.69	.0155
11.	1.25	.93	2.71	.76	1.04	1.08	.0138
12.	1.06	.85	2.14	1.46	.69	.97	.0060
13.	2.06	1.12	2.43	.98	.58	.70	.0001
14.	1.88	1.20	2.71	.76	.50	.86	.0001
15.	.81	.40	2.43	.98	.54	.51	.0001

[1]Performance data are raw scores for the first aid teams at each site on each performance item.
[2]See table 9 for description.

first- aiders make errors they may not know it at the time. In addition, unlike the paper and pencil latent image version, the role play situation exercise requires not only knowledge of what to do and when to do it, but also skill in performing actual first aid procedures without life situations, which is more difficult than the latent image version. Like a well-designed mine rescue contest, the first aid simulation is a good test of knowledge, skill, and actual performance capability.

The first-aiders in all three classes did a good job on only two tasks, properly removing the victim from under the slate (item 3), and promptly rescue-dragging the victim outby the face to get under supported mine roof (item 5) (see table 9). Both of these tasks are rescue activities and both are obvious actions.

The worst performance for all three groups of first-aiders involved conducting a victim evaluation through a primary and secondary survey (item 7), and finding and treating both leg injuries (item 8) (see tables 9 and 10). The first-aiders in class 1 and class 3 did not carry out an adequate hands-on primary and secondary survey. Consequently, they never found the compound fracture of the femur, even though it was simulated with a broken broom handle taped to the victim's right front thigh along with a large injury tag that said "MUCH BLOOD AND BONE STICKING OUT." This simulated injury was concealed underneath a pair of coveralls, and the injured miner was lying face down. Another large injury tag that said "BLOOD SOAKED CLOTHING" was attached to the outer coveralls directly over the simulated fracture. Even a cursory hands-on and/or careful visual primary survey would have quickly revealed the presence of these injury tags and the simulated compound fracture. The injured miner was loaded and tied onto the stretcher face down. Consequently the injury remained undiagnosed and untreated.

The first-aiders in class 2 carried out a victim injury assessment. Because of their survey they found, and treated, both simulated leg fractures. However, they had difficulty in properly bandaging and splinting the compound thigh fracture. The types of errors made by these miners in this realistic simulation are precisely those tasks that the 120 experts identified as weaknesses in miner actual first aid performance they had witnessed in the field (see tables 2 and 3).

Large, statistically significant differences were observed in the total performance and the individual scale scores of the three groups of first-aiders (see tables 8 and 9). The groups with the greater number of first-aiders with self-reported advanced first aid training, and with first aid instructors, performed better than the less well trained groups without first aid instructors.

LIMITATIONS AND GENERALIZABILITY OF FINDINGS

These results are based on the performance of only 12 miners who role played first-aiders coping with one complex and realistic underground coal mine first aid problem. The performance results observed may not generalize to other groups of miners or to other first aid simulation problems or actual emergencies. Additional data from the first aid simulation described in this paper, as well as from other similar simulations, are currently being collected and analyzed. These additional data will help determine the generalizability of the findings reported here.

Some additional observational data are available at the present. Two additional first aid simulation exercises have been observed during administration to two classes. In these classes the miners role playing the first-aiders also performed poorly and made the same types of errors as those reported previously. Thus, even though the sample is small, the findings from this initial study may be generalizable to the broader domain of first aid performance of miners in general.

The simulations are carefully designed to be authentic and realistic, and over 94 pct of the miners viewed them as such (see table 6). Performing the first aid procedures in front of a classroom, without any prior warning or preparation, is stressful for the first aid role players. Yet, the classroom role play situation can never be as difficult, stressful, and demanding as is coping with a similar serious injury accident in an underground mine. If miners perform poorly in realistic classroom simulations of first aid emergencies, they may perform even less well in actual mine first aid emergencies. The poor performance is probably related to lack of training in these types of first aid skills, particularly in the skills required for patient evaluation needed to define first aid treatment needs. Miners who are frequently exposed to realistic first aid simulation problems, like those described in this paper, may become more skilled in their responses to both simulated and actual first aid emergencies.

SIMULATION EXERCISES AS TEACHING AND TESTING DEVICES

Although the miners role playing the first-aiders in these three classes may not have performed well on the simulation exercise, they probably learned a great deal, as they themselves reported (see table 6). The purpose of these exercises is primarily to teach miners to be better first-aiders. The realistic nature of the exercises engages the emotional and cognitive participation of the role players and the observers. At the end of the simulation, the role players, the victim, and the observers are anxious to critique the performance, to discuss and correct errors, and to repeat and practice difficult parts of the performance until these have been mastered.

The exercises are most effective as tests in a personal sense. When the first-aider role players perform poorly, placing themselves in great danger to rescue the victim, or failing to do an evaluation of the victim's injuries, these and other errors and their potential consequences become starkly apparent in the corrective and discussion session that follows the simulation. A properly designed simulation presents a realistic problem. The problem demands the full range of performance skills required in a similar actual emergency. For this reason, working the simulation exercise tends to be a memorable experience. Many studies have shown that knowledge and skills acquired in realistic problem solving situations tend to be remembered well and are likely to be applied in actual problem situations encountered later. Knowledge and skills presented piecemeal, without being embedded in realistic problem contexts, tend to become inert. Inert knowledge fails to generalize to real world problem solving and also tends to be rapidly forgotten (Bransford (29), Gagne and Briggs (30), Halpern (31)).

It is important for miners to learn how to place and tie dressings and bandages, and to remember first aid facts and information. The teaching of first aid procedures like these, and drilling miners on recall of first aid facts, are popular instructional methods in annual refresher training classes. When these facts and procedures are presented in fragmented ways, without being placed in the context of first aid cases or problems, instruction cannot be expected to adequately prepare miners to cope with actual first aid emergencies. First aid facts and knowledge, as well as first aid skills in bandaging, controlling bleeding, and other procedures, need to be taught in the framework of realistic problems. Skills of accident scene evaluation, patient evaluation, and the identification of victim treatment needs and priorities need to be practiced. Well-designed simulation problem exercises provide one means for the realistic teaching and assessment of a wide range of first aid problem solving behaviors.

CONCLUSIONS

Well-designed simulation exercises have the capability to teach miners what they do not yet know how to do well. The research reported in this paper, as well as earlier research by Pickar (27), suggests miners need more training in information gathering, victim evaluation, and first aid problem identification and prioritization skills. Simulation exercises like those discussed in this paper can be used to teach and assess proficiency in these and other skills. Data from the field studies at Ohio State University and the University of Kentucky also suggests that college students and miners enjoy and value realistic first aid simulation problems. Length of time to conduct such realistic simulations need not be a barrier. The simulation described in this paper can be completed in a 20- to 30-min period. Knowing how to design and conduct an effective first aid simulation also need not be a barrier. The guidelines set forth in this paper, and the sample exercise with its easily adaptable format, can serve as a model for first aid instructors who wish to extend the procedures to other first aid skill areas and problems.

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APPENDIX. – SAMPLE EXERCISES

MARVIN R. LETCHER FIRST AID SIMULATION

A Training Activity

Behavioral Research Aspects of Safety and Health Group (BRASH)
Institute for Mining and Minerals Research (IMMR)
University of Kentucky, Lexington, Kentucky

November 1987

This role play simulation exercise was developed and field tested under U. S. Bureau of Mines research Contract No. HO348040. Information about the design and characteristics of the exercise and the field test results are available in the project technical reports filed with the Bureau of Mines Research Center in Pittsburg, PA. This is one of more than 30 exercises designed for use in annual refresher training to teach and test critical skills for coping with mine emergency situations. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or the U. S. Government.

Contents

MARVIN R. LETCHER SIMULATION PROBLEM

Background

You are driving 8 entries in 42 inch coal.
Eleven miners are at work on the section.
The portal is 4,000 feet outby the face.
It is just after lunch. (Marvin ate a big meal.)
The EMT normally on this section is absent today.
The top is drummy and poor.

Problem

You are the pinner operator. You are bolting the roof in the #2 entry at the face. Your helper, Marvin R. Letcher, has gone out ahead of the bolter to mark the roof. You yell at him to get back. He almost gets back to supported roof when a piece of draw slate falls trapping both of his legs. (See Figures 1 & 2.) Marvin is lying down, screaming. The roof is dribbling across the whole entry just past the last row of bolts.

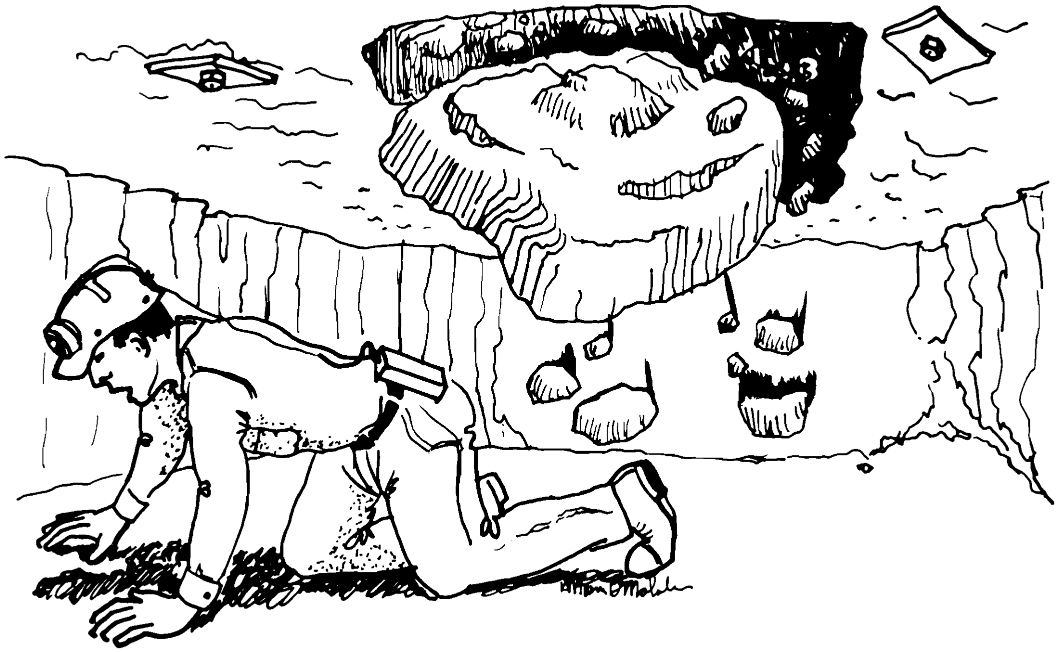


FIGURE 1.—Draw slate falls from roof.

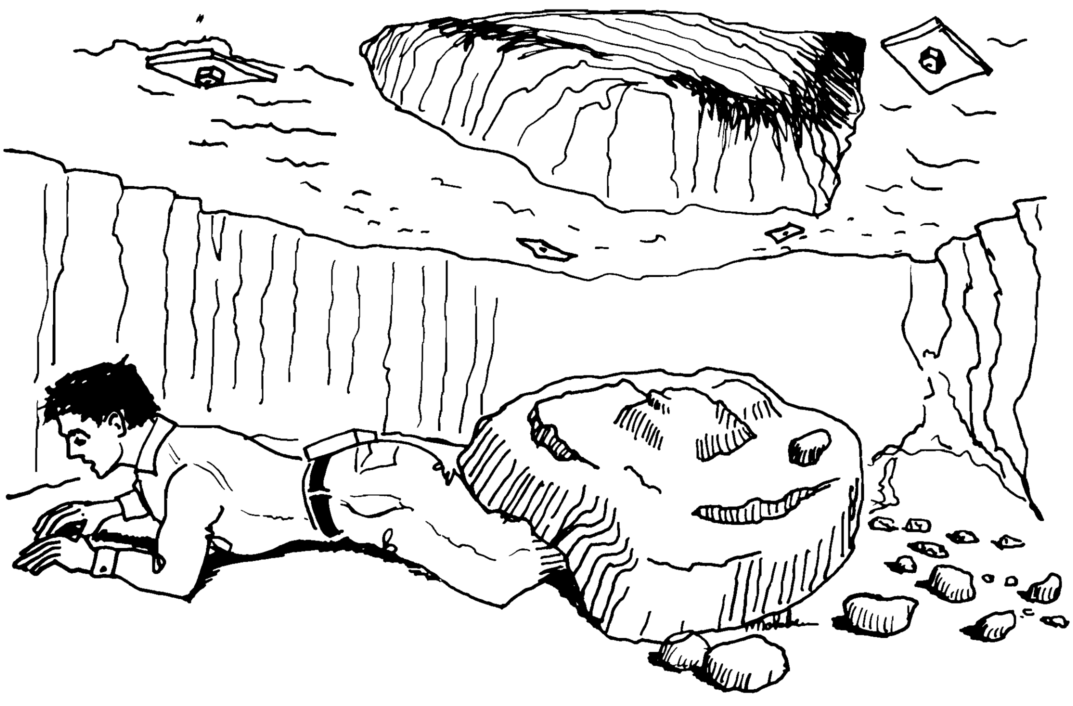
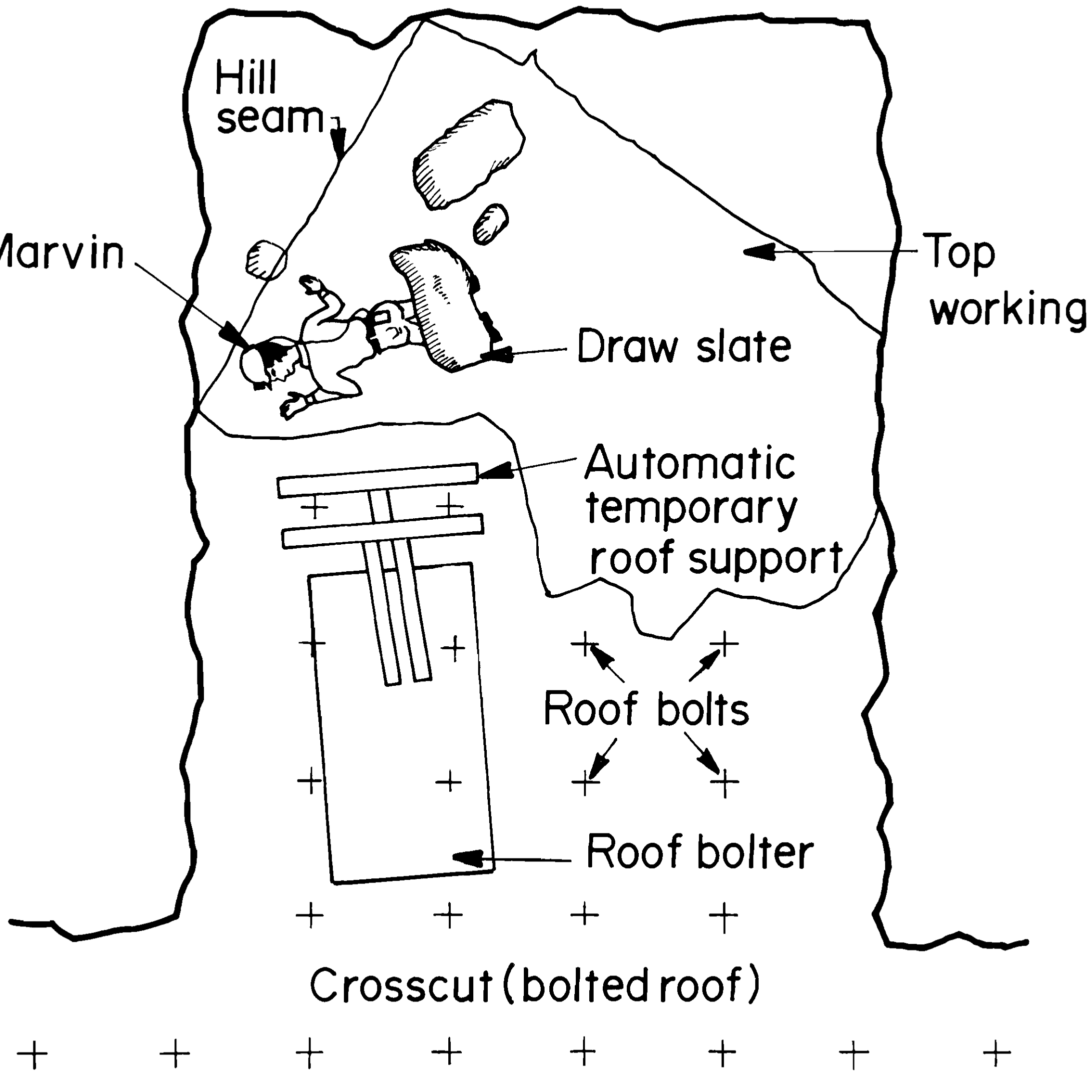


FIGURE 2.—Draw slate hits Marvin's legs.



Stretcher and first-aid kit at the dinner hole dinner hole 240 ft away.

Mine pager at tailpiece 200 ft away.

FIGURE 3.—Details of Marvin's position.

Marvin R. Letcher First Aid Simulation

This is a companion exercise to the Marvin R. Letcher latent image exercise. It uses the same problem. While the latent image exercise teaches and assesses judgment and decision making skills, this exercise is designed to teach and assess proficiency in first aid care for a miner with injuries like Marvin's.

This exercise can be used without using the latent image exercise. If so, it will be more like the situation miners would face in an actual emergency. If used after the latent image version of Marvin R. Letcher, the class members will be informed about the problem and know the first aid procedures. They will also be motivated to practice the procedures. Used either way, this simulation exercise provides hands on practice in carrying out the first aid procedures needed to help a miner with injuries like Marvin's.

The activities for carrying out this simulation are simple and easy to use. After you have read through the materials it is easy to prepare for class. Once you have prepared for one class, you can use the simulation repeatedly in other classes without additional preparation.

Becoming Familiar with the Exercise

This document is an instructor's guide. It provides not only the simulation exercise, but detailed instructions, procedures, and materials needed to prepare for class and carry out the activity. There are five things you can do to become familiar with the exercise if you decide to use it in your classes.

First, look over the Table of Contents found just after the exercise title page. All the parts of the instructor's guide are listed here and you can quickly see what these are and where they are located.

Second, read the "Marvin R. Letcher Simulation Problem" on page 2 and look at Figures 1 and 2 (page 3) and Figure 3 (page 4). Think about this situation and how you would deal with it.

Third, read through the remainder of this instructor's guide. It tells you how to prepare for class.

Fourth, read the "Performance Objectives" and the "Performance Rating Form." These are found in the appendix. They tell you what your class members should be able to do when the exercise is completed.

Fifth, if you have a master copy of the Marvin R. Letcher latent image exercise, look at the questions, the answers, and the "Instructor's Discussion Notes." Although you do not need to do this to prepare for this class, it may provide you with additional ideas.

How To Use This Exercise

This section lists the directions for carrying out the simulation. There are three parts. These explain what to do before, during, and after the simulation. Each step is numbered.

Before the Simulation

1. Gather all the materials you need for the simulation. These include:

   -slate bar (simulate or use a real bar)

   -roof bolting machine (simulate with a desk or similar object)

   -four temporary roof jacks or timbers (simulate with appropriate lightweight objects such as styrofoam blocks, or cardboard tubes)

   -large old trousers or coveralls that can be slipped over the "victim's" regular clothing

   -large flat cardboard box (to simulate the draw slate on Marvin's legs)

   -broken wooden dowel, 6 to 7 inches long and one inch in diameter (taped over Marvin's pants on his right upper front thigh to simulate a compound fracture of the femur)

   -a mine first aid kit and stretcher (Place these out of sight in another room or at the back of the room so the "first aiders" will have to go get them or send someone for them.)

   -a mine phone (Use a real phone or simulate with a small object. Place the "phone" at the back of the room at the "tailpiece.")

   -tags (These are in the appendix. Copy them, cut them out, and laminate them so they can be used again. Attach these to Marvin and the objects.)

   -"Instructions for the Victim" & "Instructions for the Rescuers" (These are in the appendix. Copy them, cut them out, and laminate them so they can be reused.)

   -Performance Rating Form, one copy for each class member (Make an overhead transparency of this form so you can use it after the simulation in the discussion.)

-overhead projector and screen

-overhead projector transparencies of the Marvin R. Letcher Simulation Problem and Figures 1, 2, and 3 (These are found on pages 2, 3, and 4. They are printed in large type for easy reading.)

2. Get a volunteer to play the part of Marvin, the "victim." (Give "Marvin" the "Instructions for the Victim" so he will know his role. If no miners are willing, get another instructor to play the role of Marvin.)

3. Select two or three miners to serve as the first aiders. (Give them a copy of "Instructions for Rescuers." Then send them out of the classroom so they won't see Marvin's injuries while you set up the accident scene. They should find the injuries on their own.)

4. Set up the accident scene. (Simulate the accident scene depicted in Figures 2 and 3 as closely as possible. Have Marvin lie down on his stomach with his head about 2 feet from a wall (mine rib), with his left side facing the class. Simulate the draw slate on Marvin's legs with a cardboard box. Simulate the roof bolter with a desk or similar object. Label both objects with the appropriate tags.)

   Have Marvin tape a broken wooden dowel and the "MUCH BLOOD AND BONE STICKING OUT" injury tag to his <u>right upper front thigh</u> on top of his pants. Then have him put on an additional pair of old pants or coveralls that can be cut. Put the "BLOOD SOAKED CLOTHING AND CROOKED LEG" injury tag on the outside of the old coveralls on top of the broken wooden dowel. Put the "CROOKED AND BRUISED" injury tag on the rear of the lower left leg on top of his coveralls, about midway between his ankle and knee. Place the cardboard box over the back of both legs so that it covers the injuries. Tape the injury tag "PULSE RAPID (120) AND WEAK" to Marvin's neck over the carotid artery. Use transparent tape. Keep the injury tag "VOMIT FLUIDS AND STRINGY MEAT" in your pocket. Tape to Marvin's cheek after the first aiders have him fully immobilized and he is ready to be transported.

5. Give every class member (except the "victim" and the "rescuers") a copy of the Performance Rating Form. Ask each class member to look over the form. This will alert them to watch for key first aid actions during the simulation. <u>Do</u> <u>not</u> give the form to the miners playing the "first aiders." This would tell them what the injuries are and what they should do.

During the Simulation

6. Bring the "first aiders" in and have them stand at the back of the room.

7. Introduce the problem to the "first aiders" and other class members by showing the overhead transparencies of the "Marvin R. Letcher Simulation Problem" and Figures 1, 2 and 3. Explain the problem and point out that the "victim" is in the same position as shown in Figures 2 and 3. (Don't tell the class and the "first aiders" about Marvin's injuries. Just explain the accident scene as it is described. Point out the "mine phone" at the "tailpiece" and explain that a first aid kit is at the "dinner hole.")

8. Tell class members to move to a position where they can see the "first aiders" and the "victim." Ask them to watch carefully and not to prompt the first aiders.

9. Start the simulation. Tell the "first aiders" to take care of Marvin. (During the simulation, do not interrupt the performance of the "first aiders." In the real situation there might not be anyone to correct their errors or to tell them what to do. Interrupt only if they do something that might hurt the person playing the "victim.")

After the Simulation

10. Give each of the "first aiders" and the "victim" a performance Rating Form. Then ask these people and all the other class members to complete the form. Have everyone complete the whole form including the information at the top of the page. (This activity will help the "first aiders" evaluate their own performance and correct errors. Completing the rating form will also help the other class members learn the correct first aid procedures. This is an important part of the exercise.)

11. Complete your own Performance Rating Form, including the information at the top of the page.

12. Discuss the performance of the "first aiders" with the whole class. (Put a transparency of a blank Performance Rating Form on the overhead projector. Talk about each procedure and your rating of the "first aiders." Compare your ratings with those of the "first aiders," the "victim," and the other class members. Be alert to the observations, ideas and disagreements among class members. Discussion of these matters can be an effective method of instruction.)

13. During the discussion, correct any errors that were made. Show the "first aiders" and other class members the proper way to carry out any first aid procedures that were done wrong or omitted. (Let the "first aiders" demonstrate the correct procedure under your direction. This will help them learn.)

14. Encourage class members to practice particular first aid procedures until they master them.

15. When you have finished the discussion and demonstrations, have all class members complete the Trainee's Questionnaire. It is attached to the Performance Rating Form. After the class, look over the completed Trainee Questionnaires. These can be used to summarize the miners' evaluation of the exercise. This information may assist you in improving the exercise in the future, and in reporting the effectiveness of your classes to superiors. If you have ideas for improving the exercise write these down and send them to the following address.

IMMR/BRASH
201 Porter Building, University of Kentucky
Lexington, Kentucky 40506-0205 (606) 257-3796

Other Information and Ideas

This section contains additional information about the exercise. It can help you plan the amount of time you need to present the exercise, how to prepare the exercise for several replications, and assist you in thinking about other ways to present the exercise.

Time

The whole simulation exercise should not take very long. In a real emergency, miners would need to act proficiently and quickly. The discussion, practice, and demonstration of procedures after the simulation may require somewhat more time. Overall, the activity can be completed in approximately one hour.

Replications

Once you have used the exercise, all materials can be kept together and used again with another class. This will minimize preparation time. You may also improvise and add new ideas and procedures in replications of the exercise.

Alternative Methods

Some trainers report miners do not like to role play situations like this one. If this is true in your classes there are some alternatives. First, a colleague can play Marvin's role. You can yourself play the role of a first aider and have two or three class members help you. While it is better to perform these skills than to watch others do so, class members can still learn a lot from watching and using the Performance Rating Form. If you follow this procedure, make sure everyone practices those particular skills you think are critical, e.g. proper movement and lifting, proper treatment for shock, proper procedures for immobilization, etc. You may wish to do this to ensure that all class members have a chance to practice critical skills. With larger classes you might have several small groups carrying out the simulation or parts of it all at the same time.

There are four other points worth noting. First, after working and discussing the latent image version of the exercise, miners are excited and attentive to the problem. Therefore, they are more likely to participate in and attend closely to the simulation. Second, you may wish to point out that exercises similar to these are routinely used to train and test EMTs, military and medical personnel, and mine rescue groups. Experience suggests that such activity is helpful in building and maintaining proficiency in the skills needed in actual emergencies. Third, no individual miner's performance is being rated. Rather, it is the quality of care the "victim" receives that is being assessed. The information gathered is for instructional purposes. Fourth, you and individual class members can learn much about the degree to which they are informed about proper first aid procedures from examining the completed Performance Rating Forms. If ratings of the class members differ greatly from your expert rating, you should determine where the disagreements lie. Then you can correct any errors or misunderstandings among class members.

Appended Materials

This appendix contains seven items. These materials are needed to carry out the simulation and the class discussion. The first item is a list of the performance objectives for this exercise. The objectives for the latent image version of the Marvin R. Letcher exercise are similar to, but are not the same as the objectives for this simulation exercise. The objectives for this exercise deal with hands on performance of first aid skills needed to rescue and care for a person with injuries like Marvin's.

Next is the Performance Rating Form. It is to be used by each member of the class to rate the adequacy of first aid procedures carried out on Marvin. You also need to complete one of these forms yourself so you can use it during the discussion period.

Next is the Trainee's Questionnaire. After the exercise is completed each miner should complete this questionnaire. It is helpful to collect these and review the class members reaction to the exercise.

The next item is the instructions for the "victim" and the "rescuers." These are printed within boxes. They are designed to be duplicated, cut out, and mounted on a card to be reused. These are the special instructions given to the persons who participate in the simulation activity.

Next are the tags. These are also printed within boxes so that they may be copied, cut out, and mounted on cards for reuse. Some tags are large and have large bold type. Others are small and have small type. The size of the tag and its type are related to the obviousness of the injury or item. For example, the pulse rate tag is small and inconspicuous while the much blood and bone sticking out tag is large and noticeable.

The next items are Figures 4, 5, 6, and 7 and may be useful in the class discussions. Finally, you will find included the references used in the design of this exercise.

Performance Objectives for Marvin R. Letcher Simulation

Objective number	Capability verb(s)	Description of desired performance and conditions under which it is to occur
1 FA/EE*	Remove Extract	A victim from under a roof fall while minimizing risk to self and victim
2 FA	Demonstrate Perform	Clothing drag procedures for the rapid but gentle removal of a victim from a dangerous place while minimizing risk of further injury
3 FA	Simulate Demonstrate	Primary and secondary survey first aid procedures given a simulated victim
4 FA	Describe Communicate	To surface personnel the nature and extent of injuries of a simulated victim
5 FA	Identify Treat	Compound and regular fractures of the upper and lower legs of a simulated roof fall victim
6 FA	Demonstrate	Proficiency in use of a mine first aid kit and a mine stretcher
7 FA	Demonstrate Execute	Procedures for positioning and lifting a simulated victim on a stretcher, supporting and immobilizing fractured legs, bandaging wounds, and full body immobilization on a stretcher prior to transporting
8 FA	Demonstrate Simulate	Procedures for identifying and treating shock, maintaining an open airway in an unconscious person who is vomiting, using a simulated victim
9 FA/EE	Demonstrate	Skill in organizing and directing rescue and first aid activity in a group setting of three or more persons given a simulated victim

*Skill and knowledge domain abbreviation:
FA = first aid
EE = emergency evacuation and escape

Performance Rating Form for Marvin R. Letcher Simulation

Instructor__________________ Company __________________ Date__________

In this problem I was a(n): (Check the appropriate space(s))

_____Victim _____ First Aider _____ Observer _____ Class Instructor

Circle the number that best describes the quality of first aid treatment you observe. Procedures are assigned a maximum value of 2, if they are expertly performed. Adequate, but not expert performance is rated a 1. Performances not attempted or poorly completed are rated 0. Add the numbers circled to obtain the total score. Look over the entire form before you begin.

	Procedure	Yes Done well	Yes Adequate	No
1.	Was the mine roof properly supported before the first aiders moved to and worked on the victim?	2	1	0
2.	Was the draw slate promptly and properly removed from the victim?	2	1	0
3.	Was the victim properly moved from under the draw slate to minimize further injuries to him and avoid risk to rescuers?	2	1	0
4.	Was the victim given verbal encouragement during rescue and care?	2	1	0
5.	Was the victim promptly moved from the entry to an area of well supported roof?	2	1	0
6.	Was the victim positioned, handled, and moved properly when moved from the entry to an area of supported roof?	2	1	0
7.	Was the primary survey properly carried out?	2	1	0

Marvin R. Letcher Simulation

	Procedure	Yes Done well	Yes Adequate	No
8.	Was the secondary survey properly carried out?	2	1	0
9.	Were both leg injuries immobilized?	2	1	0
10.	Was help sent for promptly and properly?	2	1	0
11.	Was communication about the injury to the surface clear, accurate, and complete?	2	1	0
12.	Was the victim properly positioned and lifted onto the stretcher?	2	1	0
13.	Was the victim properly immobilized on the stretcher on his or her back?	2	1	0
14.	Was the victim treated for shock?	2	1	0
15.	Was the immobilized victim's airway maintained even when vomiting?	2	1	0
16.	Overall, were the rescue and first aid efforts well organized and efficient?	2	1	0

Sum ____ ____

Total Score = ____ + ____ =

Highest Possible Score = 32, lowest = 0

<u>Comments</u>:

Marvin R. Letcher Simulation

TRAINEE'S QUESTIONNAIRE (Simulation Exercise)

1) name of exercise ______________________________

2) your age __________ 3) your sex _____ M _____ F 4) years underground coal miner ________

5) your job title ______________________________

Check all the areas in which you have special training, certification, and/or that you routinely perform.

	Special Training	Certification	Routinely Perform
6) Mine Foreman	______	______	______
7) Mine Safety Committee	______	______	______
8) Mine rescue	______	______	______
9) CPR	______	______	______
10) Advanced first aid	______	______	______
11) EMT	______	______	______
12) Advanced life support	______	______	______
13) Other (describe) ____________________	______	______	______

Think about the exercise you just finished. Circle the number which tells how much you agree or disagree with the following statements.

	Definitely Yes			Definitely No
14) This problem could happen in real life.	4	3	2	1
15) This exercise will help me remember something important if I am ever in a similar situation.	4	3	2	1
16) I learned something new from the exercise.	4	3	2	1
17) The exercise took too long to complete.	4	3	2	1
18) I liked working the exercise.	4	3	2	1
19) The instructor's directions were clear.	4	3	2	1
20) The written directions in the exercise were easy to understand.	4	3	2	1
21) The diagrams and tags were easy to understand.	4	3	2	1
22) The scoring procedures were easy to understand.	4	3	2	1

If you have anything more to say about the exercise, please write on the back of this page. Thank you.

INSTRUCTIONS FOR THE VICTIM

1. Scream for help and pretend to struggle to get out from under the draw slate.
2. After your buddies get the rock off you get weaker. Moan and say your legs hurt.
3. As your buddies move you, act dazed and sleepy. Then you act like you are passed out.
4. When your buddies have you fully tied down on the stretcher, pretend you are vomiting but still passed out.

INSTRUCTIONS FOR THE RESCUERS

1. You are upset by Marvin's screaming and the accident.
2. Use good first aid procedures to rescue and care for Marvin and take care of yourselves.

DRAW SLATE

(Put on box.)

ROOF BOLTER

(Put on desk.)

ROOF JACK

(Put on simulated jack.)

ROOF JACK

(Put on simulated jack.)

ROOF JACK

(Put on simulated jack.)

ROOF JACK

(Put on simulated jack.)

MUCH BLOOD AND BONE STICKING OUT

(Put on right front thigh on victim's pants under coveralls.)

BLOOD SOAKED CLOTHING

(Put on right front thigh on top of coveralls.)

MINE PHONE

(Put on phone at back of room)

BRUISED & CROOKED

(Put on Marvin's left rear lower leg outside coveralls.)

Rapid weak pulse (120)

(Put on Marvin's neck over the carotid artery.)

VOMIT FLUIDS & STRINGY MEAT

(Keep in your pocket until Marvin is fully tied down on the stretcher. Then attach to his cheek.)

<u>Additional Illustrations</u>

Use overhead transparencies of these illustrations during the discussion to help demonstrate proper techniques for moving, lifting and immobilizing Marvin.

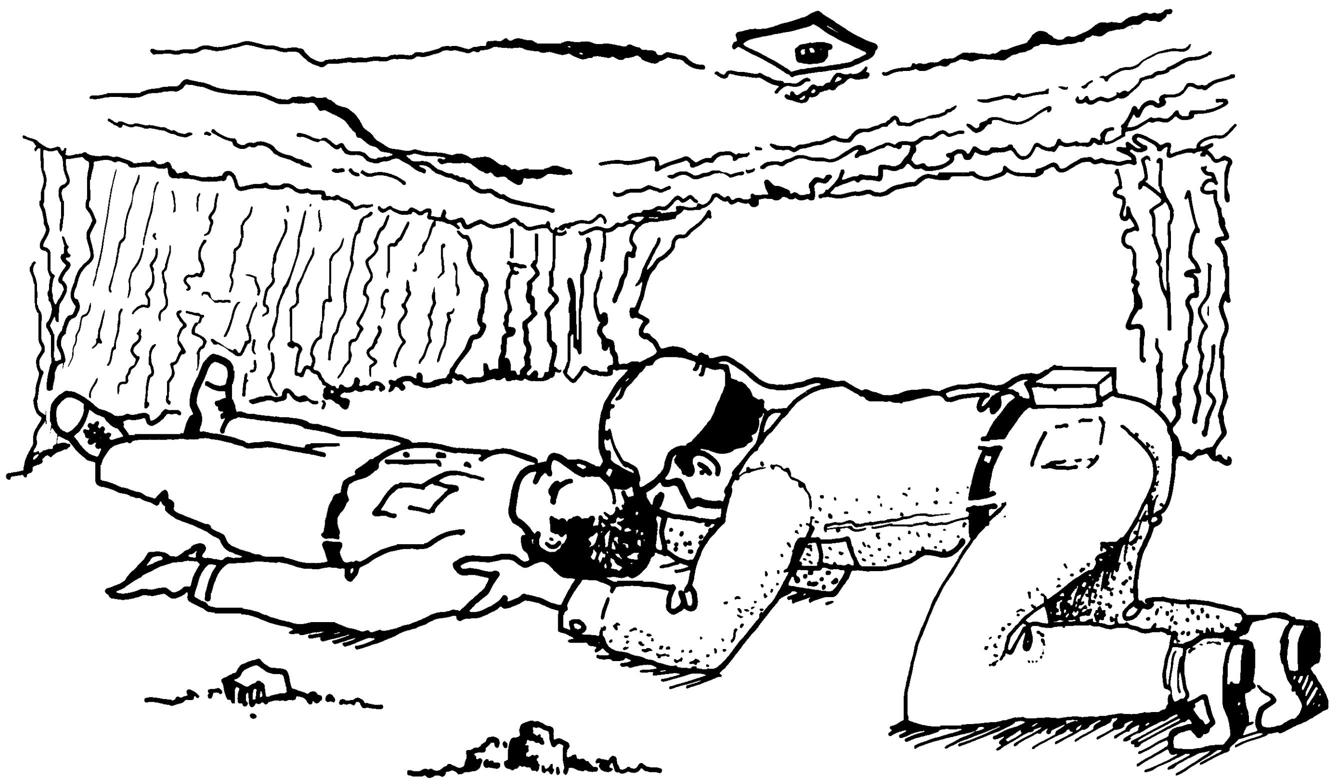


FIGURE 4.—Emergency one-rescuer clothing drag.

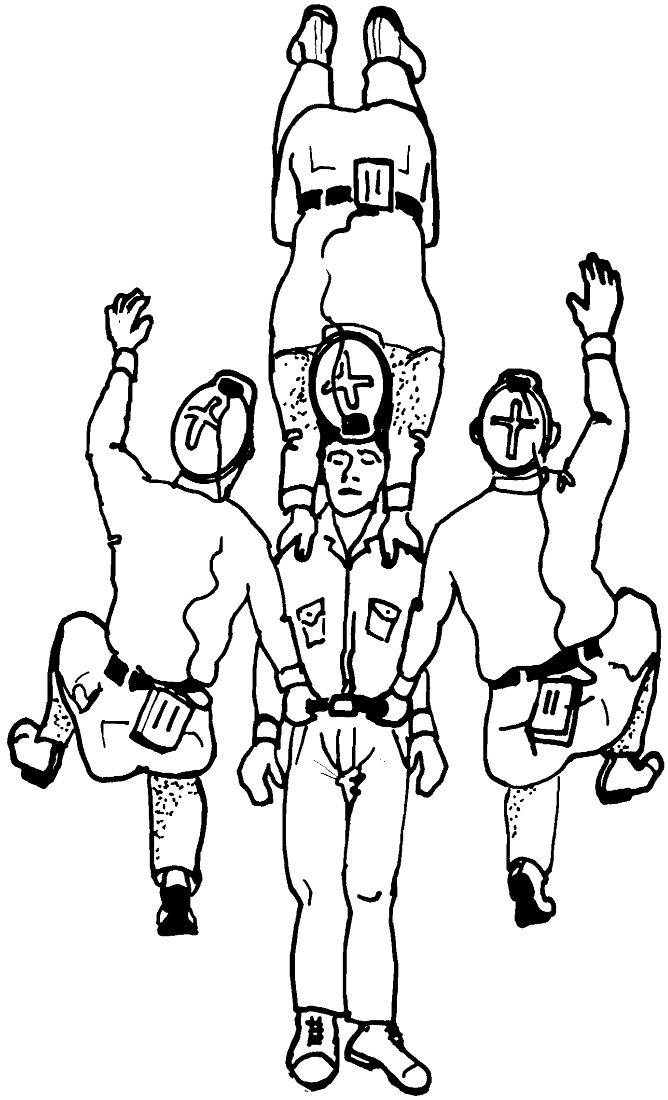


FIGURE 5.—Emergency clothing drag with three rescuers.

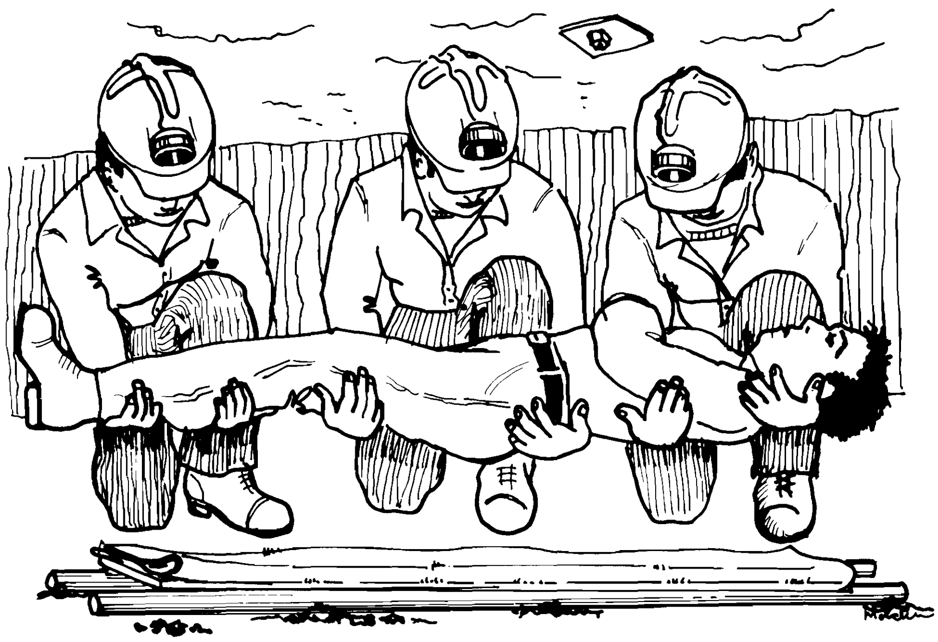


FIGURE 6.—Three-person lifting procedure for moving injured person.

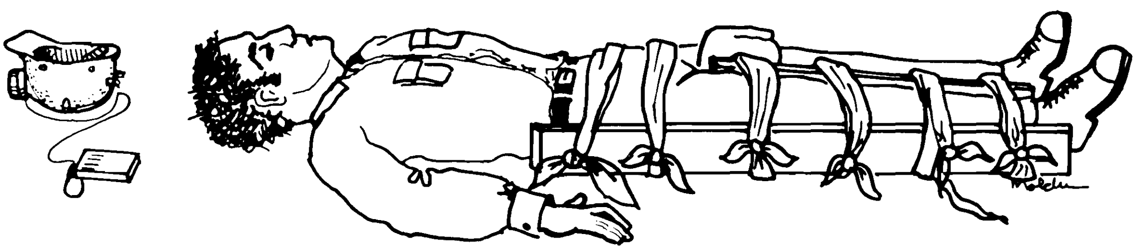


FIGURE 7.—Ties for immobilizing Marvin's leg fractures.

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