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An Overview of Research on Self-Contained Self-Rescuer Training

By Charles Vaught, Michael J. Brnich, Jr., William J. Wiehagen, Henry P. Cole, and Henry J. Kellner

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

Cover: Miners attempting to don their SCSR's in smoke.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

h	hour	pct	percent
in	inch	s	second
min	minute		

AN OVERVIEW OF RESEARCH ON SELF-CONTAINED SELF-RESCUER TRAINING

By Charles Vaught,[1] Michael J. Brnich, Jr.,[2] William J. Wiehagen,[3] Henry P. Cole,[4] and Henry J. Kellner[5]

ABSTRACT

In 1985, U.S. Bureau of Mines and University of Kentucky researchers began a series of studies relating to self-contained self-rescuer (SCSR) donning proficiency. During the next 5 years investigators examined a number of factors that have a bearing upon miners' ability to put on and use the apparatus in an emergency: the procedure being taught; availability and utilization of training models; opportunities to practice; hygiene; and on-the-job training. This report presents an overview of that research. It is concluded that companies should adopt a hands-on training protocol that allows them to integrate SCSR donning practice into other workplace routines such as fire drills.

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INTRODUCTION

This overview is part of the U.S. Bureau of Mines mission to improve the health and safety of the Nation's miners. Oxygen-breathing apparatus have been available for use during underground mine emergencies in this country since 1907. These devices were intended to be worn by people engaged in rescue and recovery after such events as fires and explosions. Apparatus were donned in fresh air and wearers then proceeded inby to explore or work. The popular conception of such activities today often represents employment of the device as not being a problem: mine rescue personnel put their apparatus on and then use them to do whatever needs to be done. This was not always the case. Morrow (*1*)[6] noted that in the beginning: ... it was not unusual for one, two, three, or four men to put an apparatus on and make, or attempt to make, explorations ahead of fresh air after mine disasters.... Often these men had little or no previous training in wearing the apparatus other than a few oral instructions.... Under such conditions it is not strange that men collapsed and lost their lives while wearing oxygen breathing apparatus, but rather it is surprising that a greater loss of life did not occur...."

The deaths of several men in succession led to the adoption in 1921 of mine rescue standards (*2*). These standards provided a baseline for training. The schedule for initial instruction, which took approximately 20 h over a 5-day period, included 9 h of practice wearing the apparatus. The Bureau recommended additional instruction and practice be given at least once every 6 months (*3*). With increased industry commitment over time, there emerged gradually a cadre of fit, well-trained, and highly motivated individuals for whom donning and use of the device was, indeed, rather nonproblematic. The end product of this historic process can be seen today in mine rescue team members who benefit from tested protocols for employment of their breathing apparatus and who receive frequent opportunities to practice.

With the introduction of self-contained self-rescuers (SCSR's) in 1981, another oxygen-breathing apparatus became available for use during underground mine emergencies. This device was deployed with a different philosophy in mind. Whereas the older apparatus had always been intended for use by a few individuals in rescue and recovery work, SCSR's from inception were meant to be donned and worn by rank-and-file miners during escape attempts. Whereas Bureau researchers had concluded in 1959 that "... the safe use of oxygen breathing apparatus depends on carefully selected, well-trained men...," these new oxygen rebreathers were to be employed by universally trained workers who would be chosen by circumstances. Furthermore, miners might well have to don the devices in smoke or bad air, rather than in comparative safety, before going into a life-threatening situation.

Given the Bureau's early concern about deaths associated with inadequate training on oxygen-breathing apparatus, what would this universal instruction for SCSR's be like? Berry and Mitchell (*4*) noted that the Training and Education Committee, Coal Mining Section of the National Safety Council (NSC), released a memorandum in May 1980 making certain preliminary recommendations. These suggestions are included in part here and will be discussed later:

1. "Despite the differences among brands of SCSR's, only one procedure should be taught... preferably [depicted] in bold, easily understood graphics."
2. "Training models should be as low in cost as possible. Fidelity is not important. What is important is being able to put on an SCSR and practice procedure. Breathing resistance is not critical, nor are features such as the case being manufactured to the same standards as the actual model. Low cost promotes greater use of models and therefore more actual practice."
3. "Throw-away or easily cleaned mouthpieces are necessary on the training model."
4. "The first phase of training should be classroom; then build training into fire drills and other on-the-job training."

In essence, the committee seemed to have cut to the heart of some of those principles central to motor-task training: give individuals a simple schema to follow; let them practice the entire task often; and incorporate this practice into their everyday activities.

In the case of oxygen-breathing apparatus, as history already had shown, an approach like that recommended by the committee was critical. Yet, the committee's suggestions did not get translated into a general program of action by the industry. Why not? A few of the possible, and very plausible, reasons will be discussed in the section that follows.

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

BACKGROUND

Cole and his colleagues (*5*) conducted interviews with more than 50 mine safety experts from a cross section of organizations during the summer of 1985. In the process, they recorded several accounts of miners' failure to put on their SCSR's in situations that clearly called for their use. The general assumption of those individuals discussing such failures was that the workers involved knew *how* to employ their apparatus but did not because of poor judgment or even panic. There was little or no speculation that rank-and-file miners in the early 1980's might just be in the same position regarding *their* oxygen-breathing devices that would-be rescuers in the 1920's were with the apparatus they had to use. Once again, could there not simply be a lag between technology and training?

This notion was borne out not only by some of the findings from the Wilberg disaster (*6*) and the Greenwich Collieries explosion (*7*), but also by impressionistic data supplied by a mine safety trainer who had carried on an exercise with workers at his operation. The exercise consisted of having groups of miners don one of the compressed-oxygen SCSR's and travel several breaks through heavy smoke in their return. The trainer summarized his observations in the following manner: (1) people had to be prompted while putting on the apparatus; (2) about one-fourth of the workers forgot to don their noseclips; (3) roughly a dozen individuals, out of 96, did not use the goggles; (4) some 10 pct of the total group did not get their oxygen turned on; (5) several miners got the SCSR neck straps tangled with their cap lamp cords; and (6) at least two people did not get the mouthpiece in and sealed correctly. All in all, if one considers the intended function of SCSR's, this portrayal of workers' level of proficiency with the apparatus is disturbing.

Why would worker ability to don and use an SCSR be taken for granted by the aforementioned mine safety experts in the first place? After all, had not the Bureau already gone through one program of remediation for insufficient training on oxygen-breathing apparatus? There are several credible answers to this question, some of which were touched upon by Cole (*5*) and his colleagues. Each is considered in turn and circumstantial factors will be offered as support for the conclusions reached here.

First, the success of mine rescue training itself may have had a bearing upon how SCSR's were viewed at the time of their initial deployment. Morrow (*1*) noted that for the period from October 1940 to July 1959 there was not a single known death among wearers of permissible oxygen-breathing apparatus in American coal mines. In other words, lessons from the early part of this century had been learned and their antecedents forgotten, leaving an effective protocol in place. Donning and use of the device when the occasion demands it simply has not been perceived as a problem in the recent past.

This mine rescue protocol seems to have provided the model for self-contained self-rescuer training in 1981. For example, original instructional materials to be used in SCSR training are strikingly similar in form to materials developed for mine rescue training (*8-10*). Both sets of instructions provide information on how the apparatus works and discuss conditions under which it is to be employed. Both sets of instructions present a donning procedure in which an individual is pictured standing in a well-lighted room and going through a sequence of approximately a dozen steps in order to secure the device for wearing. Finally, both sets of instructions warn that the apparatus should be worn only by individuals who are trained to don the device, but, assuming training, present wearing in a nonproblematic way.

A second reason SCSR donning and wearing skills may have been taken for granted so long is that there was little empirical data at first to refute the notion that need will somehow be translated into ability. This confused linking of cause and effect is typical in many areas: an object exists for a certain purpose; therefore, it is taken for granted that the object will serve the purpose intended. In the case of mine rescue devices, the data showing that oxygen-breathing apparatus might not automatically serve their intended purpose were deaths attributable to misuse. In the case of SCSR's, the first data were donning times for 46 workers participating in a field evaluation of two prototype models (*11*). While these donning times ranged from 30 to 196 s, there was no indication of the types of errors being committed, nor of their frequency. In the absence of concrete performance data, anyone wishing to assess the proficiency of miners with oxygen-breathing apparatus would be forced to fall back upon impressionistic accounts or fatalities in which inadequate training was implicated.

The problem with impressionistic data or deaths attributable to misuse of an apparatus highlights the third reason SCSR donning and wearing ability may have been taken for granted by the industry at large. Without empirical evidence to the contrary, each event in which something goes wrong can be passed off as a discrete incident rather than seen as part of a larger pattern. For instance, while training at the Wilberg Mine was called into question after the disaster in 1984 (*6*), there was no blanket questioning of training practices at all operations. To repeat, one reason for this is that there was no baseline of data from which to draw inferences. The other reason is probably that there was not a series of deaths such as had occurred with rescue apparatus after 1907. Thus, any doubt about the Wilberg miners' proficiency with SCSR's became just one of many issues that arose during the investigation at that site rather than coming to the forefront and causing a general questioning of miners' ability to use oxygen-breathing apparatus such as had ensued in the 1920's.

A fourth explanation for why Cole (*5*) and his colleagues uncovered little doubt about workers' ability to use SCSR's if they needed to may lie in the nature of how training was mandated. While training for mine rescue fell under its own subpart (49.8) in 30 CFR, self-rescue training was included as one of several mandatory courses in Parts 48 and 75. The provisions for mine rescue training required an initial 20-h course of instruction in the use and care of the type of apparatus that was to be employed. This was to be followed by refresher training that included wearing and use of the device for at least 2 h every 2 months. Initial training for SCSR's, though, was fit into the required course on self-rescue and respiratory devices such as filter self-rescuers (FSR's) and respirators. The course called for instruction and demonstration in the use, care, and maintenance of self-rescue and respiratory devices employed at the mine. This was to be followed by refresher training annually.

The entire program of annual refresher training, under which continuing instruction on SCSR's was subsumed as a small part, is 4 h less than the time mine rescue team members are required to spend just on wearing and using oxygen-breathing apparatus. Since there are only so many hours in a day, and only so many items that can be given attention under Part 48, it is easy to see how SCSR training could be inadequately covered. Instruction in the use, care, and maintenance of SCSR's would be no more or less important from a compliance standpoint than the rest of the course dealing with FSR's and respirators. The "self-rescue devices and respiratory devices" course itself would be no more or less important than the dozen or so other courses offered in that 8-h time span. Thus, just as a trainee is assumed to be able to identify and avoid electrical hazards after instruction, or to put on and breathe through an FSR, so would he or she be assumed to be able to don and use an SCSR if the need arose.

Essentially, it seemed that even though modern-day mine rescue protocols might have influenced the *form* of SCSR training materials and procedures, the *substance* of training on this oxygen-breathing device was more nearly like that given to workers before 1921: "Often these men had little or no previous training in wearing the apparatus other than a few oral instructions..." (*1*). The last bit of evidence that miners' proficiency with SCSR's was a non-issue can be seen in the following conclusion from Cole's research, which is very similar to Morrow's observation quoted earlier about the state of instruction before 1921: "The interviews support a widely held notion that very few underground coal miners ever actually don an SCSR in training. Rather, the typical training session will include a film, a slide-tape presentation, or a talk by an instructor who stands before the class and demonstrates the steps involved" (*5*).

The following sections will discuss a series of studies begun shortly after the Wilberg disaster. Rather than attempt to deal with all aspects of SCSR usage, such as whether workers know what to expect while wearing a device during an escape, these studies made donning proficiency the central issue. They addressed one by one each element that seemed to arise as a barrier to good SCSR donning training and evaluation. The long-term goal of this research mission has been to secure the same industry commitment to donning proficiency with these new oxygen-breathing devices as was given to training on the first oxygen-breathing devices following promulgation of the Bureau's mine rescue standards in 1921. As will be seen, this is an attainable goal and a necessary first step in any effort to ensure miners are able to use their apparatus in an emergency.

DEVELOPING ONE DONNING PROCEDURE

The preliminary study, which was carried out by University of Kentucky researchers on a Bureau contract, satisfied the first recommendation of the NSC's Education and Training Committee: "Despite the differences among brands of SCSR's, only one procedure should be taught...." The motivation for this effort lay in the research team's perception, mentioned previously, that the wrong sort of model had been used to guide development of the original training materials and recommended donning procedures.

It should be emphasized that the researchers did not consider these SCSR training materials necessarily bad in and of themselves, nor did they consider procedures recommended by these materials impossible to learn. Rather, it was thought that the general information advocated a training approach that was not appropriate for the real-life conditions a person attempting to don and use an SCSR might encounter. Quite simply, every aspect of the original instructions seemed to convey a sense of the routine in discussing what to do in a situation the investigators pictured as being anything but routine. There were logical reasons for making this inference, and they primarily involved differences between mine rescue operations and self-rescue activities as perceived by the researchers.

A mine rescue team member would probably put on his or her apparatus while standing in a well-lighted area. Since this person could secure the breathing device and be checked out before going into bad air, there might be little hurry to get his or her lungs isolated. Instead, attention probably should be paid to making sure the apparatus was on right and in good working order. Also, since the mine rescue team member would be highly motivated and very well trained, there would not be much need to present him or her with a simplified, easily remembered donning procedure.

A rank-and-file miner might very well have to put on his or her apparatus in a smoky entry in low coal where the only lighting would be provided by his or her cap lamp. In such a predicament the device would have to be donned quickly; it would have to be put on while working in an awkward position; and the lamp would have to be used to illuminate what was being done. Unlike a mine rescue team member, this person would not be highly trained in the employment and use of a breathing apparatus. If one can imagine this situation the value of a straightforward, easy-to-learn, and easy-to-remember donning procedure is readily apparent.

Given the preceding two scenarios, it was felt that existing SCSR training materials were better suited to a mine rescue model than to a self-rescue model. First, the pictured donning positions appeared unrealistic from a self-rescue point of view. As mentioned previously, instructions generally showed an individual donning the apparatus while standing in a well-lighted room. It was not clear from looking at the materials how to handle the various parts of the device to be discarded, some of which almost invariably get entangled with straps and lamp cords. Nor was it clear what was to be done with the cap and cap lamp: Hang the cord around one's neck, letting the cap dangle down the side? Remove and replace the cap as one completes various steps? Some illustrations showed the cap without a lamp, thereby avoiding this question altogether. A second concern stemmed from the fact that the donning sequence tended to put nonessential and time-consuming tasks such as strap adjustment ahead of some of the steps necessary to isolate one's lungs from the surrounding "mine" atmosphere. The demonstrator first inspected the seals and pressure gauge and then performed those tasks necessary to allow him to work with the unit while standing. Only then did he complete the steps needed to get his lungs isolated. The final critical tasks, such as putting on the noseclips, might come as late as tenth in a sequence of 14 or more steps. Third, the materials presented no simplified, easy-to-remember procedural rules to help miners order the complex array of tasks needed to use the SCSR in an emergency.

As a first step toward developing a procedure that would be directed at the hypothetical miner attempting to don an apparatus in a low smoky entry, the researchers conducted an experiment in cooperation with a coal company in eastern Kentucky. Three groups of workers were chosen to put on an SCSR during annual refresher training. A baseline group (number (N) = 14) was selected from among surface workers at the operation. These individuals had never received training on SCSR's. They were included to see if this oxygen-breathing device was simple enough to be put on by anyone who knew what it was for but who had not been shown how it worked. A control group (N = 20) had initial hands-on training using the manufacturer's materials and recommended donning procedure in 1981. They had been given their most recent annual refresher demonstration 7 months before. A treatment group (N = 16) was similar to the control group in terms of experience except that they got a demonstration just before their performance trial.

The donning trials were conducted individually in a private room at the company's training center. Each person, when brought into the room, was equipped with a pit belt, FSR, cap, and lamp. The SCSR was placed on the floor in front of him or her. At a signal from the researchers the individual attempted to put on the SCSR as if he or she were in an emergency. Investigators videotaped the entire donning sequence.

Nobody was able to don his or her apparatus "proficiently," if by that term one infers some ability to put on an SCSR well enough to do what the instruction handbook advocated: secure the device and retreat from a hazardous area. Regardless of that criterion, figure 1 shows that many of these workers did not even get their lungs isolated by activating the oxygen, inserting the mouthpiece, and donning the noseclips. This failure probably could be explained away for the baseline group since they had received no instruction in how to employ the SCSR. What was remarkable at the time was that a full third of the others also failed to isolate their lungs.

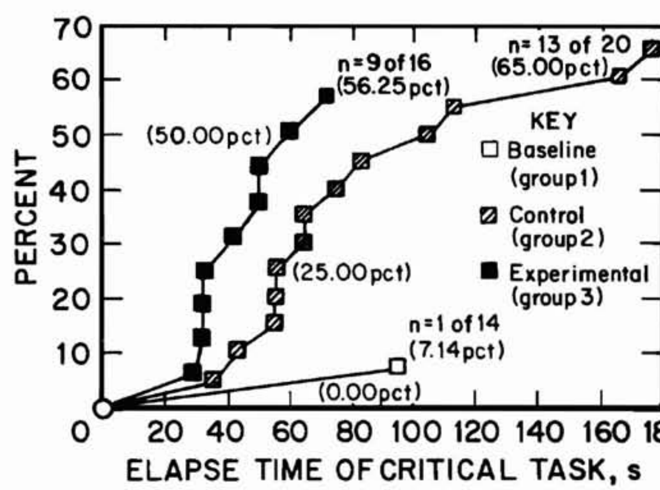


Figure 1.—Percent of trainees getting lungs isolated.

The research team drew some preliminary conclusions from this initial study. First, any lingering notions that SCSR's were somehow intuitively simple were discarded. Investigators confirmed, to their satisfaction, at least, that they were dealing with an apparatus that was on roughly the same order of complexity as other oxygen rebreathers. In that case, oral instruction or demonstration in no way would constitute adequate initial training. Second, insofar as mandated training on self-rescue and respiratory devices required infrequent refreshers, it was decided that a 12- or 14-step donning procedure was inappropriate because workers could not remember it. Third, since many coal miners labor in low seams, the recommended donning position was determined to be unworkable for a sizable part of the population.

Based upon these conclusions, the research team set about devising a more rationalized training system for SCSR's. This system was to have one primary function: to maximize workers' gains in donning proficiency while minimizing the amount of resources and level of effort companies would have to expend beyond what the regulations already required. The program to be developed was never intended as a panacea. Instead, it would involve the logical application of a few proven task-training principles to achieve what was hoped might be a significant enhancement of performance.

To begin this process the investigators conducted an extended task analysis of the videotaped donning trials. Generally, it was found that individuals had little or no notion of step sequencing. This was indicated by the fact that a subject would often interrupt one task to begin another, and complete neither. Also, in addition to omitting steps, many workers would perform incorrectly one or more of those tasks he or she attempted. The overall picture was one of people trying to do something they did not know or remember how to do.

It is much easier to remember to do tasks in a proper sequence if the entire process is laid out in some logical and simple framework that organizes them all "naturally." Sensitized by their task analysis, the researchers next turned their attention to discovery of this logical framework. They operated from an assumption that even though there were different brands of SCSR's the apparatus had one common imperative: to enable workers to get their lungs isolated in a mine emergency. Consequently, the most pressing or "critical" steps should be to get the oxygen started, to insert the mouthpiece properly, and to put on the noseclips. After that the "secondary" steps, those necessary to get the SCSR secure and ready for travel, could be performed.

A round of hands-on tinkering and experimentation followed in which the investigators began to make minor tradeoffs among the various devices in order to reach an optimized and generalizable donning sequence. Since some workers would not be able to stand up while putting on the apparatus, but all could kneel, the advocated position for donning would be kneeling. Since straps had proven to be a time-consuming and confusing element, strap adjustment would be undertaken after the lungs had been isolated. This could occur because the individual would be kneeling with the SCSR lying on the mine floor. However, because managing the neck strap was a problem once a miner's lungs had been isolated, it was decided that the neck strap should be looped over the head prior to anything else being done. In this manner the research team worked step by step toward a logical pattern of actions that would enable workers to don their apparatus efficiently and effectively.

The result of this effort quickly became known as the "3+3" donning method. Using this method a miner in an emergency would place the apparatus on the mine floor in front of his or her knees. After removing the cap and placing it on the floor so that the cap lamp could illuminate the SCSR, the worker would loop the neck strap loosely over the head. Once this was done, he or she would complete the following "chunked" sequence of steps (fig. 2): (1) activate the oxygen; (2) insert the mouthpiece; (3) put on the noseclips; then (4) don the goggles; (5) adjust the neck and waist straps; and last (6) replace the cap and move out.

It is easy to see that the new 3+3 procedure was a generalized prescription for how to put on any SCSR then existing regardless of brand. It was assumed that before an individual tried this method he or she would have been shown how to do the discrete tasks, such as opening the case and activating the oxygen. What people tend to forget most quickly is not how to perform the independent tasks once learned, but in what sequence these tasks should be done. For that reason it is crucial to lay out steps so that the completion of one leads logically to the next, which in turn cues the recall of those tasks which are part of that step. Likewise, it is important to "chunk" tasks into as few steps as possible since the fewer steps one has to remember the more likely he or she will be able to sequence them correctly.

The donning method was field tested during workshops conducted for a dozen groups of coal industry people in Kentucky. Each group was given a short videotaped demonstration of the 3+3 sequence, and individuals then underwent performance trials in a manner that was to provide the standard training-evaluation protocol for subsequent studies.

Prior to each donning trial the individual was equipped with a miner's belt, cap, and cap lamp. An SCSR was placed on the floor in front of the subject. The trainee was requested to await a signal from the trainer, and at this signal to put on the SCSR as if he or she were in an actual mine emergency. No questions were answered or

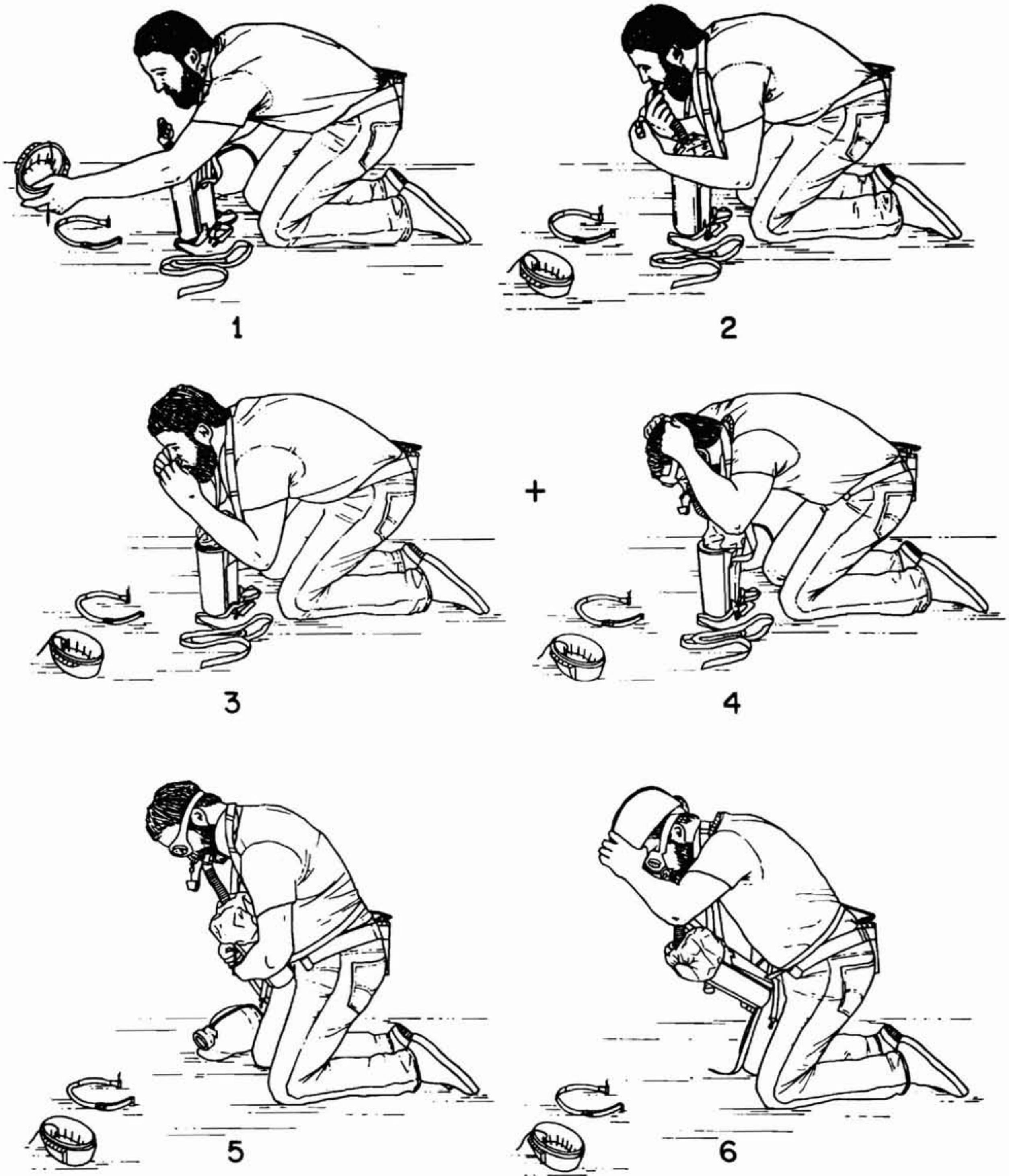


Figure 2.–The 3+3 donning sequence.

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. This form, which has proven highly reliable in hundreds of trials, is intended to show sequencing errors and actions that are done incorrectly (fig. 3). A helper recorded times for 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.

Almost all of the people, 172 of 179, in these 12 workshops were able to complete the critical tasks and isolate their lungs. Furthermore, unlike those miners in the first study, many workshop trainees, an overall average of 46 pct, performed a perfect sequence on their initial try after seeing the new demonstration. The data summary is shown in table 1.

The research team, upon achieving such a promising display of ability in the workshops, next began incorporating the 3+3 donning method into a complete training package. The package consisted of (1) a short videotape and (2) an instructor's manual. The videotape conformed to sound instructional principles in that it was brief and kept procedural knowledge (needed to put the SCSR on) separate from declarative knowledge (needed to care for the apparatus). The instructor's guide was divided into three parts: (1) instructions in how to conduct an effective training class; (2) line drawings of the 3+3 donning sequence, suitable for making overhead transparencies; and (3) an evaluation form that would allow trainers to assess their students' performance and offer feedback. A major objective of this package was to facilitate hands-on training.

Table 1.—Data collected from SCSR donning workshops

SCSR type and site	Test date	Critical time, s			Secondary time, s			Prior donning[1]		Perfect donning sequence, pct of total
		N	Mean	SD	N	Mean	SD	Mode[2]	Number[3]	
Draeger:										
E. Kentucky	1/22	7	17.00	5.77	7	55.00	20.78	NAp	NAp	28.57
	1/28	27	23.89	10.61	27	64.70	29.08	3	12	62.96
	1/29	15	20.47	4.93	15	52.20	19.18	0	11	53.33
W. Kentucky	3/18	16	16.25	4.97	17	41.12	17.09	0	6	22.22
	3/19	17	17.53	6.71	18	59.17	19.45	0	11	38.89
Ocenco:										
E. Kentucky	1/22	11	26.27	5.87	11	79.45	26.16	NAp	NAp	63.64
	1/29	11	33.73	10.00	11	82.45	24.11	0	9	45.45
W. Kentucky	3/18	16	26.44	5.66	15	69.06	25.42	0,1	3,3	[4]11.76
	3/19	17	38.64	11.10	19	84.32	19.08	0	16	47.37
CSE: E. Kentucky	1/22	9	21.67	4.77	9	68.88	17.95	NAp	NAp	66.67
	1/29	16	24.94	11.39	16	62.44	20.91	0	9	64.71
MSA: E. Kentucky	1/29	10	17.90	5.15	10	51.50	14.35	0	8	50.00

N Number in population.
NAp Not applicable.
SD Standard deviation.
[1]Experience with this model.
[2]Most frequently occurring value in a set where different values may occur more than once.
[3]Number of people who gave the modal response for their group.
[4]Of the 17 trainees, 9 adjusted the straps before donning their goggles. Although this deviates from the perfect sequence, it is not a critical error.

Performance Evaluation for ______________________ Date ____________

1. Did the miner answer the following?

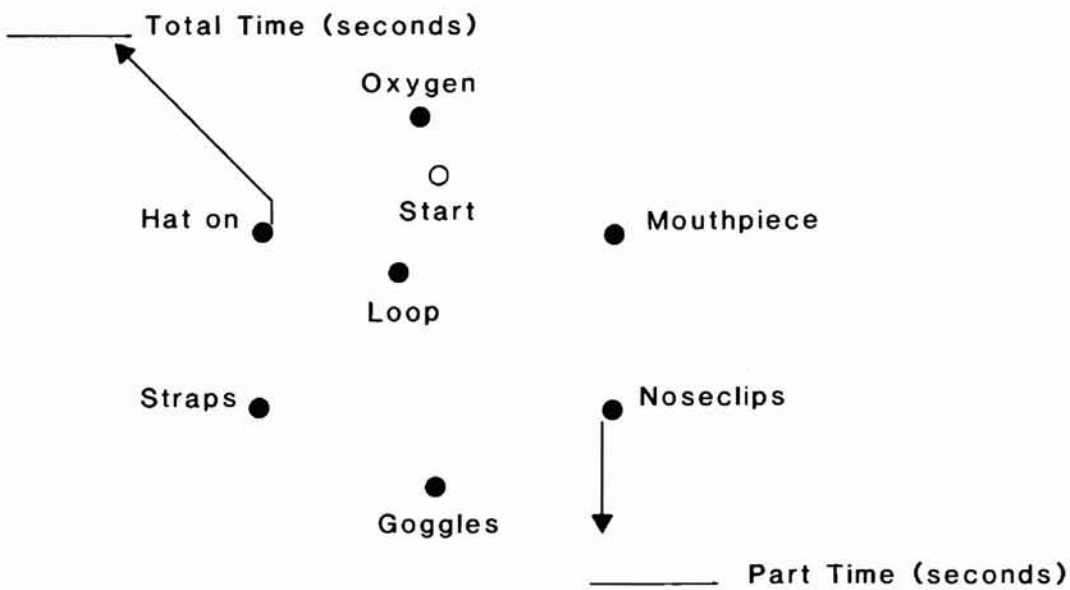
   A. Name the exact place where you started working last shift.

      ______ 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 3.—Evaluation form for SCSR training.

PROMOTING MOTOR-TASK PRACTICE

The second round of studies, which were conducted primarily by Bureau researchers, dealt with the second piece of advice that was put forward by the NSC's Education and Training Committee: "Training models should be as low in cost as possible.... What is important is being able to put on an SCSR and practice procedure...." Impetus for these studies lay in the Bureau team's perception that not only was hands-on practice not being done widely in the industry, but that many did not realize the potential consequences of not providing such training. People practice motor tasks so they will not forget how to do steps correctly, but "...people can't remember what they didn't learn..." (*12*).

In order to assess those factors influencing people's learning and subsequent forgetting of SCSR donning skills, investigators ran a training experiment with 155 professional and technical employees at the Bureau's Pittsburgh Research Center. This effort, undertaken in July of 1986, focused upon two elements of interest. First of all, researchers wanted to determine the optimum way to transfer instruction to trainees before practice. Second, team members wanted to characterize skills degradation during the coming year. Regarding instruction before practice, Schmidt (*13*) presented some evidence that the way in which a task is introduced has an impact upon how well that task is learned. Because there has been little empirical analysis of this phenomenon, however, it was decided to vary conditions prior to practice in the training study. The task was the same for everyone: learn to perform the 3+3 donning sequence on a Draeger OXY-SR 60B.[7] Groups were selected at random to be given one of three treatments before practice: a computer-based program that presented the 3+3 method as sequential blocks of information; a structured lecture that depicted the procedure in a series of overhead transparencies; and a step-by-step donning demonstration by a trainer followed up with a short videotape meant to portray the routine in real time.

Following this introduction, trainees were asked to don the SCSR while being evaluated. The variable of interest at this point was their first trial. The upper graph in figure 4 shows what happened. Essentially, a significantly greater percentage of those given the demonstration treatment were able to perform a proficient sequence, getting all steps completed properly during their initial attempt to put on the apparatus. Since live demonstration is likely to be a trainer's preferred way of presenting the SCSR donning task, this finding was encouraging.

Being able to perform a task satisfactorily immediately after seeing it demonstrated does not, unfortunately, ensure a person's ability to repeat that same procedure sometime in the future. In order to illustrate this important principle of motor-task training the research team next established a performance baseline by having participants repeat their donning trial until a perfect 3+3 sequence was achieved. So, regardless of how it was introduced or whether it was recorded on their first attempt or their fifth, all individuals ended this training session at a uniform 3+3 criterion. Ninety days later 72 of the subjects were reevaluated. The sample was apportioned evenly with 24 individuals taken from each treatment group. Overall, only 13 people, 18 pct, were able to replicate their

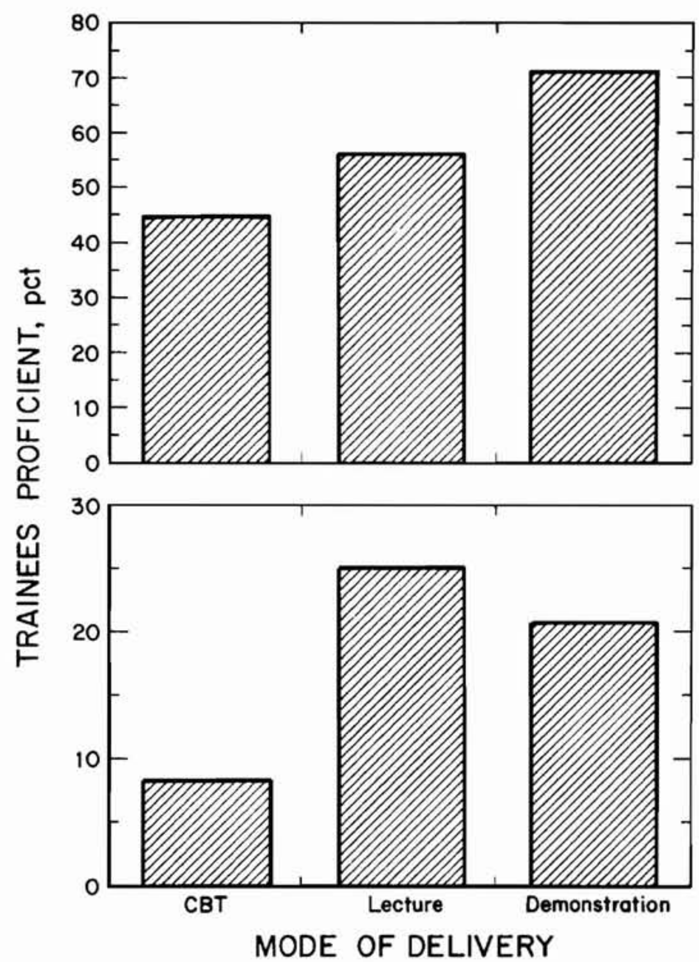


Figure 4.—Donning proficiency by mode of instructional delivery. Top, immediately following training; bottom, 90 days after training (CBT = computer-based training).

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

final perfect performance of 3 months before. Their distribution among the three delivery modes is indicated by the lower graph in figure 4. An additional 12 individuals, 17 pct, performed well enough to get their lungs isolated and the apparatus secured. Essentially, then, a mere 35 pct of the sample completed those steps necessary to enable them to escape.

The lesson emphasized by this phase of the research is simple. Even good SCSR training, which allows individuals to keep trying a procedure until they perform perfectly on the day they are trained, will not keep most of them from forgetting very quickly. Actually, what people require in order to retain their skills is distributed practice. A prerequisite for repeated practice over time, however, is access to usable training devices. Therefore, the research team decided to develop an inexpensive and hygienic simulator that could be employed to provide hands-on practice under a range of different training situations and physical conditions.

Figure 5 shows a schematic for one of the training simulators, a facsimile of the Draeger OXY SR-60B that utilized a discarded case as its basic component. Besides being low cost and highly durable, the apparatus was built with a feature that makes repeated practice relatively easy for trainers and trainees alike: a quick-release hose clamp that allows mouthpiece assemblies to be changed out in seconds. This means that each miner being trained may have his or her own previously cleaned mouthpiece, which can be installed as the device is being repacked.

"Throw-away or easily cleaned mouthpieces..." was the third critical criterion for good SCSR training mentioned by the NSC's Education and Training Committee. The reason mouthpiece assemblies are so important is that workers should be taught to perform a complete donning

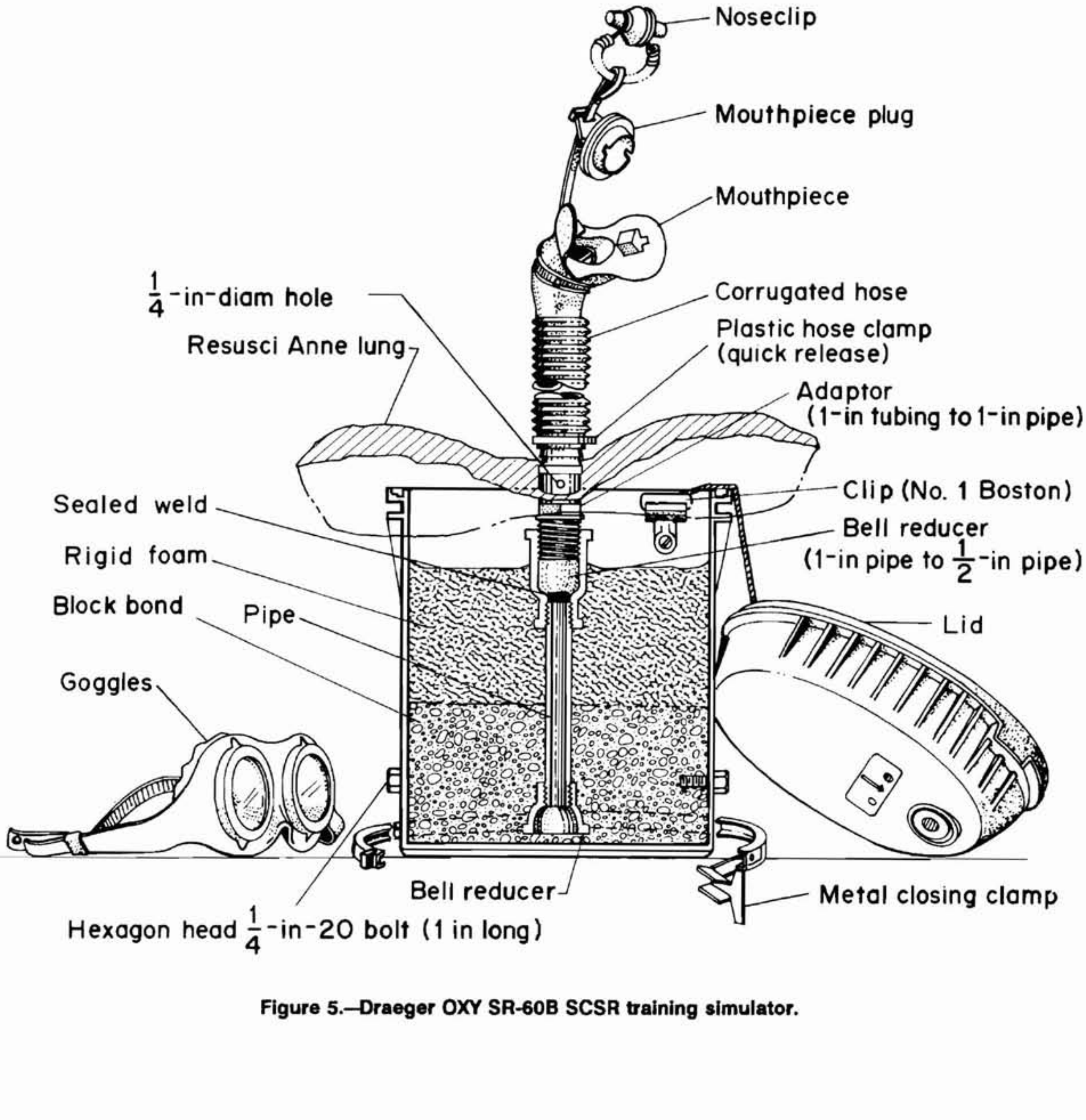


Figure 5.—Draeger OXY SR-60B SCSR training simulator.

sequence with no shortcuts. Such an approach is, first, a sound motor-task training principle (*13*). Additionally, though, empirical evidence gathered by the research team revealed that the single biggest cause of observed failures, in a sample of working miners trying to put on the apparatus in use at their operation, was mouthpiece error (*14*). This error alone accounted for 38 of the 86 observed failures. Table 2 summarizes this finding.

Table 2.—Failures due to mouthpiece errors

Errors	Sample trained to insert the mouthpiece		Total
	Yes	No	
Mouthpiece:			
Number	9	29	38
Pct	25.0	58.0	44.2
Other Critical:			
Number	27	21	48
Pct	75.0	42.0	55.8
Total number . .	36	50	86

To ensure that they could safely recommend miners be taught to insert the SCSR mouthpiece as part of their hands-on instruction, Bureau personnel conducted two microbial tests of mouthpiece assemblies that had been used in training by three organizations (*15*). Organization A employed a chemical cold sterilant to disinfect its mouthpieces and Organization B used a bleach-water solution. Organization C, which had supplied its miners with their own mouthpiece to be used with the Bureau's training simulators, simply cleaned the assemblies with soap and water after each use. Both a standard plate count and an anaerobic plate count indicated that there were no microorganisms for each mouthpiece tested. The researchers decided to adopt a protocol in which used mouthpiece assemblies would be thoroughly washed in soap and water, soaked in a bleach-water solution for 10 min, rinsed in plain water, air dried, and packaged individually in plastic sandwich bags.

Within 3 years after beginning their investigations the research team had developed a standardized donning technique, perfected an evaluation system that would yield reliable data on how well people performed this procedure, built an inexpensive and hygienic training simulator, and established a baseline from which to assess how quickly people forget what they have been taught unless they get a chance to practice. It was felt that most of the barriers to motor-task practice, be they perceptions that such training was not really necessary or that the logistics were too intimidating, had been shown to be surmountable.

INTEGRATING TRAINING INTO THE WORKPLACE

Concurrent with their efforts to promote motor-task practice, Bureau researchers entered into a cooperative agreement with a mine in the Western United States. This study had the effect of meeting the fourth suggestion that has been listed from the NSC memorandum: "The first phase of training should be classroom; then build training into fire drills and other on-the-job training." Such advice points up a crucial precondition for enhancing SCSR donning proficiency by means of distributed practice. No operation is likely to hold its workers outside for a shift every few weeks or months in order to let them practice putting on an apparatus. Yet, if it can be shown that good hands-on SCSR training may be conducted without affecting production, recommendations that miners be given periodic refresher practice seem much more reasonable.

At the western site, training began in the classroom with a short videotape demonstrating the 3+3 method and providing some tips on how to care for the device in use at that operation. Then miners went to work and the research team set up their equipment in an outby location. During the shift workers were "bumped out" on their face jobs one at a time and sent to the training area. There each miner was given hands-on instruction with repeated practice before returning to the face.

Half of the miners were trained with the regular, Draeger, training model while half were trained with the Bureau-designed simulator. Training was alternated between the two devices. The protocol used at this mine was to give the first worker a regular training model and slowly direct him or her through the 3+3 sequence as the device was donned in a step-by-step manner. The SCSR was then repacked by a trainer. The individual was next asked to put on the apparatus unaided while being evaluated. Trials were repeated until the miner recorded five perfect performances in a row. If an error was made on any attempt, this error was explained and trial performances started over. The second person was given a simulator and trained in exactly this same way. Even given so many repetitions of performance trials, the average time spent with each worker was 25 min. All 88 employees at this operation were trained to criterion without slowing down production.

The first follow-up evaluations were conducted 3 to 5 days after training. A random sample of 32 miners, or

8 from each crew, was selected for assessment on their sections. Four workers from each crew had been trained with a simulator and four had been taught using a regular training model. For this evaluation the regular training device was used. Table 3 shows that within a week of being trained most of the workers could still put an SCSR on proficiently. Furthermore, there was no difference between the performances of those who had gotten their initial instruction with the simulator and those who had been trained on the regular training apparatus.

Table 3.—Follow-up evaluation by SCSR training device

Performance	Draeger	Bureau	Totals
Failure	1	1	2
Survivor	3	3	6
Criterion	12	11	23
Total	16	15	31

About 90 days later another sample was chosen for evaluation. As figure 6 suggests, these miners' skills degraded as sharply as those of subjects included in the degradation study at the Pittsburgh Research Center. After 3 months, however, a new element was added at the western mine. Safety personnel began integrating SCSR practice and evaluation into escapeway travel and fire drills. So, when Bureau researchers returned periodically to conduct further donning assessments, they found proficiency levels holding at a reasonably high degree.

The relatively good overall performances of workers at this site can be compared to those found in a canvass of eight eastern mines conducted by the research team in early 1989. In all 243 men and women, or approximately 30 at each site, were sampled for this study. Following their standard protocol, Bureau researchers set up in a crosscut outby the last open break, and workers were sent back one at a time so that production was not interrupted. The miners were given a training model of the apparatus deployed at their mine and asked to put on the device unaided while being evaluated. If an individual made any mistakes, these were pointed out in feedback utilizing the 3+3 evaluation form (see figure 3). The worker then returned to his or her job.

Figure 7 shows a graphic profile of proficiency in the samples at those eight mines. In short, skill levels ranged from a low of 90 pct *non*proficient to a high of 63 pct proficient. The proficiency rate of the best mine in this sample, 63 pct, where workers had been trained only a week before being evaluated, does not compare favorably with that of the western operation which had roughly the same percentage of proficient miners several months after training. Again, a commitment by the western company to provide good initial training and then integrate donning practice and evaluation into their other emergency preparedness activities seems to have paid off.

Further evidence of the effect recency of training has upon performance can be seen in figure 8. To compile this graph Bureau personnel sorted individuals across all eight samples by the length of time they reported since their last annual refresher. It should be noted that this constructed time-line is confounded by the fact that training was conducted by various instructors using different apparatus, so that it has heuristic value only. Given this caveat it still appears that, as figure 6 suggests, there will be lowered skill levels among those who have had more time to forget.

By the time this phase of their research was over, members of the Bureau team had spent hundreds of hours underground conducting hands-on training and doing

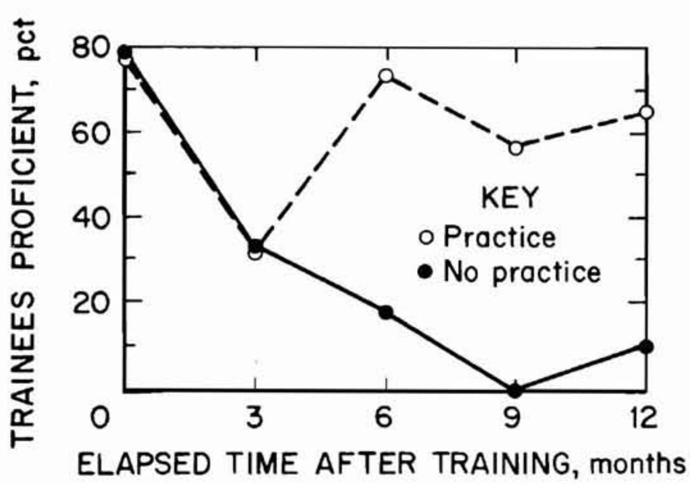


Figure 6.—Donning proficiency for workers receiving post-training practice versus those receiving no practice.

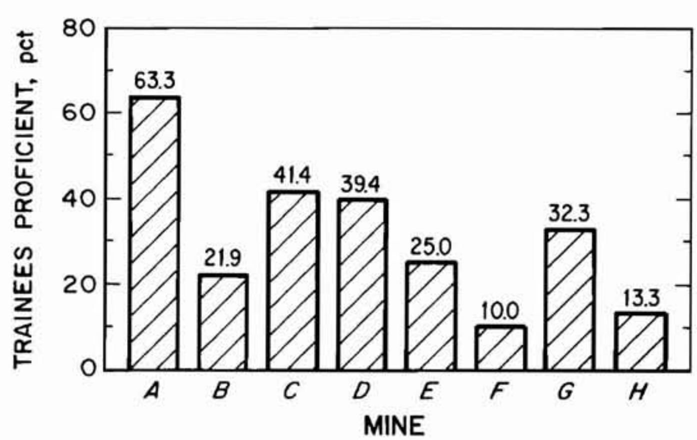


Figure 7.—Donning proficiency for the samples at the eight mines.

follow-up evaluations. They had done much to demonstrate, empirically, the following reasons the NSC Committee's admonishment to "...build training into fire drills and other on-the-job training..." should be institutionalized:

1. Short-cuts or omissions in initial training get passed along in the form of lowered proficiency - "...people can't forget what they didn't learn...." Even good initial training will be forgotten rather quickly, though, unless individuals have an opportunity for distributed practice.

2. It generally takes between one and three trials, after prepractice instruction, for a miner to master donning the SCSR. Instruction, from start to finish, including repacking the training apparatus, takes an average of 15 min per worker. In other words, good in-mine training is neither a costly nor time-consuming intervention.

In sum, it is practical to deliver high-quality hands-on training, evaluation, and feedback without interrupting production. The best, and least interruptive, means of providing that continued practice workers need in order to keep their SCSR donning skills is to build it into other emergency preparedness routines. If this is not done, many miners will quickly forget how to do the task adequately.

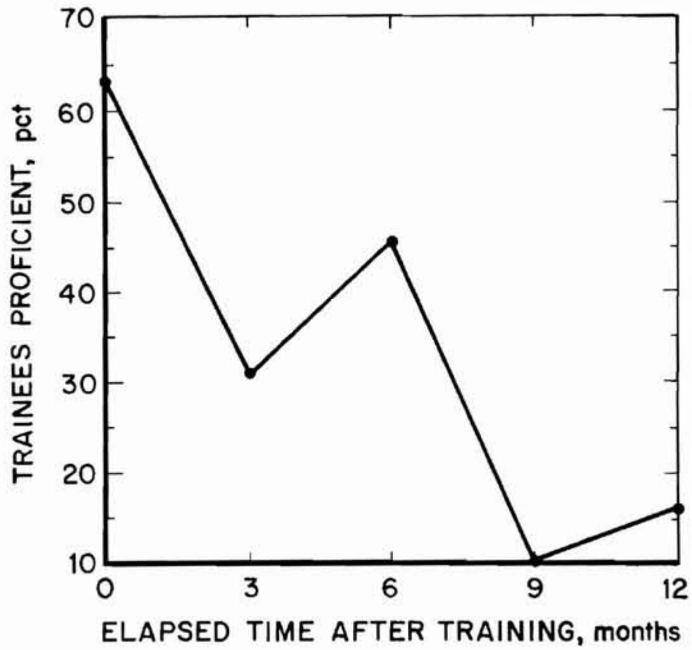


Figure 8.—Average SCSR donning proficiency for miners sampled in the eight-mine study.

TRAINING AND THE SECOND GENERATION OF SCSR's

The worst case of forgetting encountered by Bureau researchers occurred during field evaluations of CSE's new SR-100 Person-Wearable Self-Contained Self-Rescuer (PWSCSR). One hundred and sixty-nine people from a cross section of mining methods and conditions were instructed in the 3+3 procedure according to the Bureau's standard training protocol. Before returning to interview workers who wore the PWSCSR in field trials, personnel selected seven mines at which to conduct follow-up donning evaluations. As with the initial in-mine training and evaluation, researchers went to the working section and set up an interview and donning area in a crosscut outby the working face. Following an interview and answering of a questionnaire, every miner was asked to don a PWSCSR training apparatus as if he or she were facing an emergency. This trial was videotaped and evaluated.

All follow-up donning evaluations were conducted about 90 days after the miners had been trained. Figure 9 presents a pie chart showing performance trials for the 77 individuals who were sampled. The chart indicates that, despite having been trained to perfection originally, about 90 pct performed so poorly that they may be regarded as having almost completely forgotten how to put on the device. The poor showing of these people reinforced what had already been found out about losses of donning proficiency for first generation SCSR's due to a lack of frequent and systematic practice. The only element of surprise was a greater than expected magnitude of forgetting.

It was thought that some of this forgetting might be brought about by confusion. The research team hypothesized that individuals who have used the 3+3 to master one device might still experience trouble when confronted with another type. This notion was based on existing research that indicates "...the amount of transfer seems to be quite small and positive unless the tasks are practically identical..." in which case, and under the right conditions, "...negative transfer can be produced..." (*13*). Such evidence suggests that once a person has learned to do a task, he or she will be able to transfer a small degree of this learning to similar tasks. Under certain circumstances, however, subtle differences in procedure can create cognitive confusion.

There are some interesting implications in both of these observations as they apply to SCSR training. First, to achieve proficiency in SCSR donning, there must be a substantial front-end investment of time and effort on the part of trainers and trainees alike. When the necessity of training people on two apparatus is factored in, this time cost increases significantly, especially if there is little or no task transfer. Second, if there is actually negative transfer, with

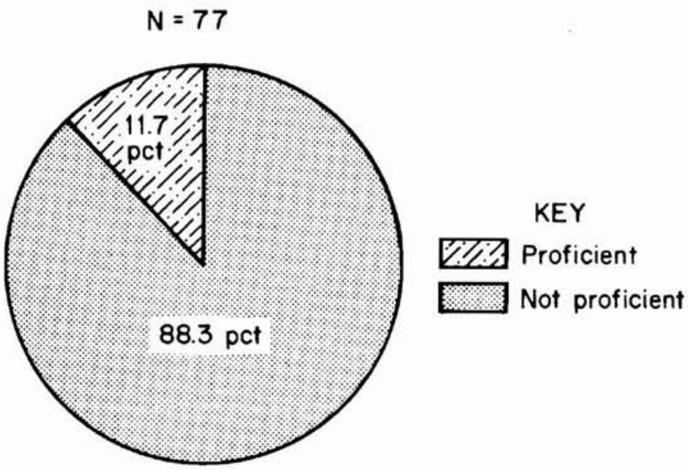


Figure 9.—PWSCSR donning proficiency 90 days after initial training.

practice on one device tending to create confusion when the individual is confronted with another type of apparatus, ways must be found to ensure proficiency on both SCSR's.

Three random samples totaling 41 workers were involved in this part of the study. All these individuals had, since 1986, been trained annually on the Draeger. Their last retraining had been conducted approximately 1 year before the present experiment. Fifteen workers were chosen to constitute a control group. The others were either retrained to don the Draeger or taught to don the PWSCSR.

Immediately following prior instruction the subjects were required to practice until they had reached the criterion goal of being able to perform a perfect sequence. They were then given a donning trial, using not the apparatus they had just been trained on, but the other type of device. There were, therefore, two treatments included in this assessment. Treatment 1 consisted of training a sample of subjects on the PWSCSR, and once they had demonstrated competence on this device, having them don the Draeger. Treatment 2 had individuals trained to criterion with the Draeger undergo an evaluation on the PWSCSR. For purposes of the present study, these performances would permit researchers to assess certain aspects of both positive and negative task transfer as individuals changed from one apparatus to another.

Subjects' performances on the trials following instruction were divided into two categories: (1) not proficient—those who did not get their lungs isolated from the ambient atmosphere (or) those who succeeded in getting their lungs isolated, but who did not secure the apparatus well enough to allow them to escape (or) those who isolated their lungs but who secured the apparatus in such a fashion that it would have allowed escape only under favorable conditions; and (2) proficient—those whose performance, although not perfect, made them escape ready (or) those who had a perfect 3+3 sequence on the first trial. Figure 10 contains pie charts that present the observed performances for those evaluated on the apparatus that was the diametric of the one they had just been trained on (Draeger or PWSCSR). These charts may be compared with that of the control group who were not trained recently, but were evaluated with the device they had last attempted to don a year before.

An examination of the areas in these charts is interesting. Essentially, there was a greater proportion of proficient sequences for those trained on the PWSCSR, but evaluated on the Draeger, than was found among the control group. Conversely, there was a smaller proportion of proficient sequences for those trained on the Draeger, but evaluated on the PWSCSR, than had been exhibited by the control group.

Another way to look at performance is by examining types of errors. Figure 11 provides an accounting of errors made on each task by apparatus used. An examination of the figure shows that the areas where people seemed to have the most trouble were in activating the oxygen, inserting the mouthpiece, donning the goggles, and adjusting the straps. These omissions are relatively serious, and would impair a person's ability to escape. In each category there were more errors committed by people who had been trained on the Draeger but who were donning the PWSCSR. As a matter of fact, at least some of those trained on the Draeger who then attempted to don the PWSCSR had problems with each step in the donning task, except remembering to replace their hard hats. Achieving adequate strap adjustment was problematic for both groups, but especially for those trained on the Draeger and evaluated on the PWSCSR. Actually, this subtask did not tend to transfer well in either direction.

In sum, this part of the study addressed an important problem related to the anticipated deployment of new person-wearable SCSR's, even when the training method is the same for all apparatus. This issue involves task transfer, or what happens when individuals taught to don one device attempt to put on another type of apparatus. If, as common sense would indicate, there are differences in the degree of difficulty each SCSR confronts the individual with, then it might be expected that the task of putting on an apparatus would transfer better in one direction than in the other. Particular attention should be paid to achieving and maintaining proficiency on the device people have the most trouble learning. While this does not obviate the need to give thorough hands-on training with each type of SCSR, it presents a cautionary note to instructors who are in the process of introducing new apparatus. This introduction must not be done casually.

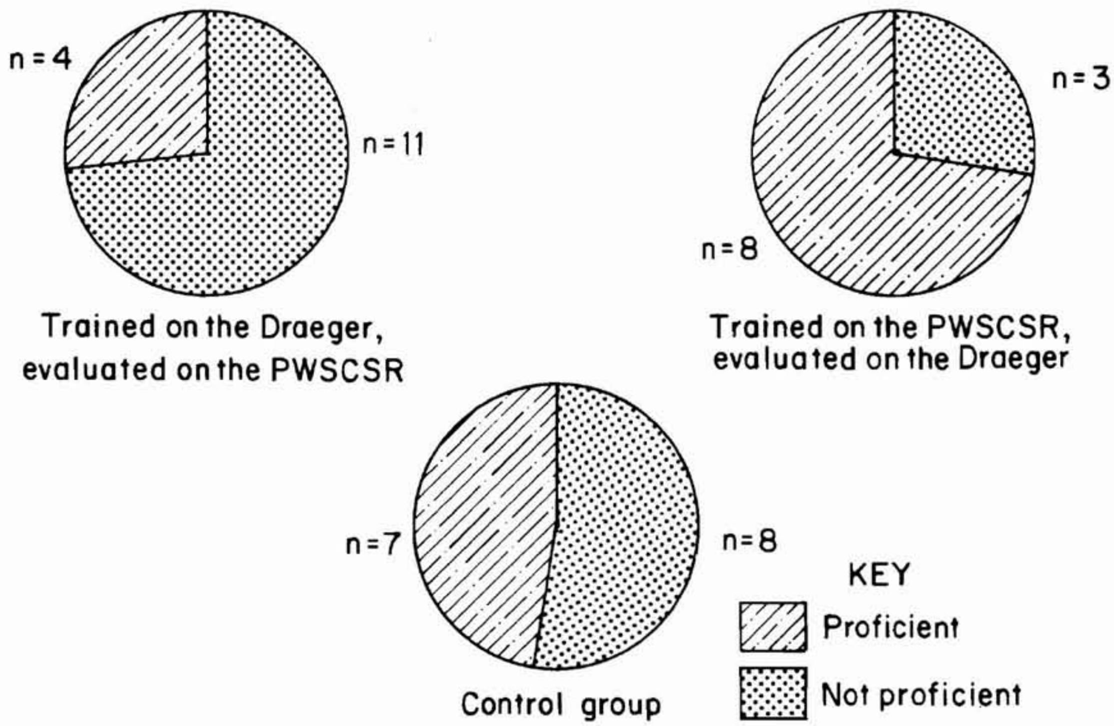


Figure 10.—Performances for individuals trained and evaluated on different apparatus.

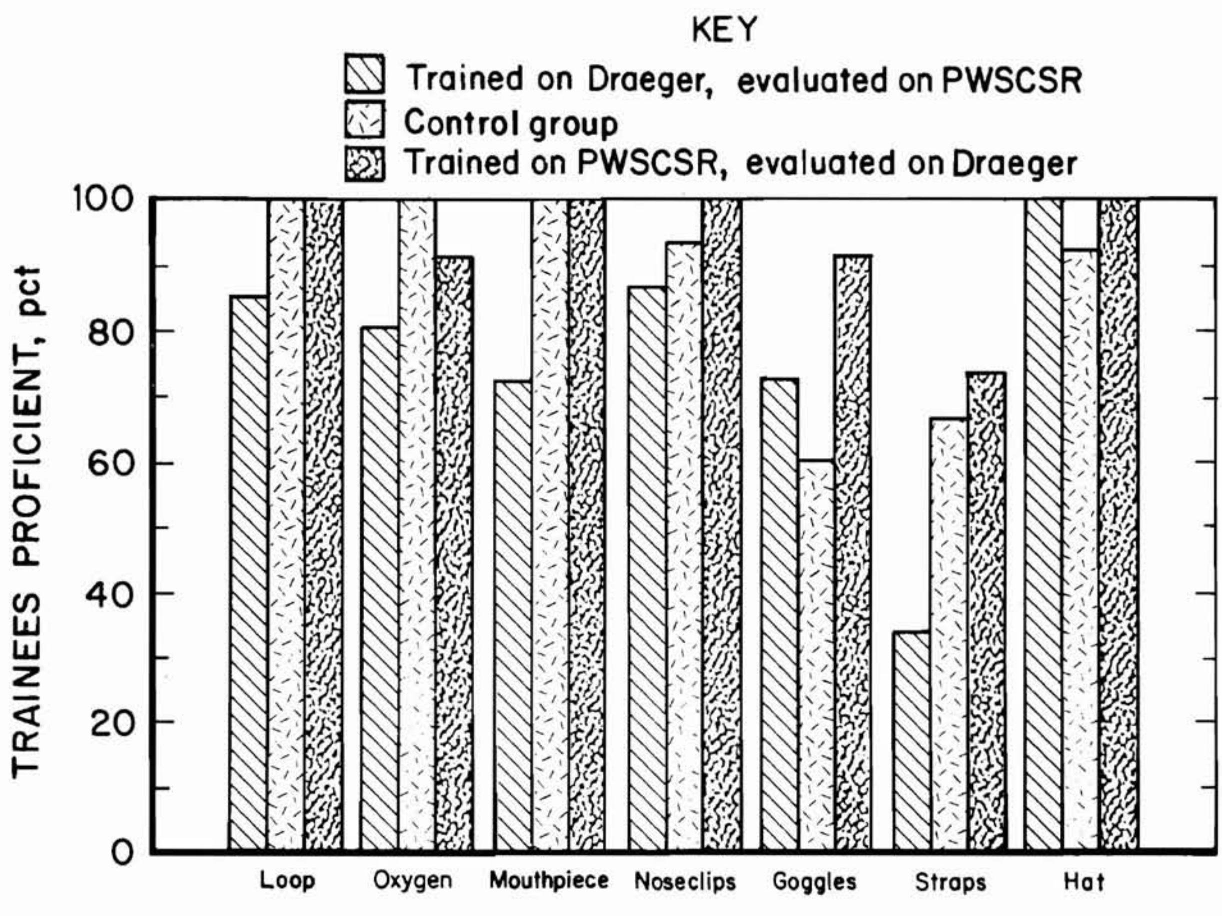


Figure 11.—Percent of individuals correctly completing each donning step.

One of the more remarkable findings from motor-skills research deals with the effect mental practice has on concrete task performance. Various studies have shown that covert rehearsal can lead to a large positive transfer of skills when a particular task is actually attempted (*13*). With these findings as a guideline, Bureau personnel decided to design a simple device that would provide an opportunity for distributed mental practice of the cognitive elements related to PWSCSR donning. Their intention was to help workers maintain procedural proficiency between hands-on practice sessions with a device that could be used in a variety of situations.

This device is a 3-D Viewmaster viewer reel depicting a miner performing the 3+3 donning sequence: open and loop; (1) activate oxygen; (2) insert mouthpiece; (3) put on noseclips; (4) put on goggles; (5) adjust straps; and (6) replace cap. It was hypothesized that once an individual had learned those discrete actions involved in putting on a PWSCSR, he or she would benefit from reviewing the steps by using a Viewmaster viewer (fig. 12). In this way a person, once trained, could prepare mentally for his or her next performance by running through the sequence periodically.

A small number of state inspectors to whom the PWSCSR was being issued by their organization were trained using the 3+3 donning method. The participants were then given a Viewmaster viewer and reel showing the sequence of steps they had just learned. A freshly trained group that was similar demographically, which constituted a control, was given nothing. Those receiving viewers were asked to use them and mentally practice the donning procedure at a regular time during every workday. Approximately 90 days after training these participants were evaluated. Figure 13 illustrates how the two groupings fared in terms of proficiency (perfect or adequate) and nonproficiency (marginal, poor, or failing to isolate the lungs).

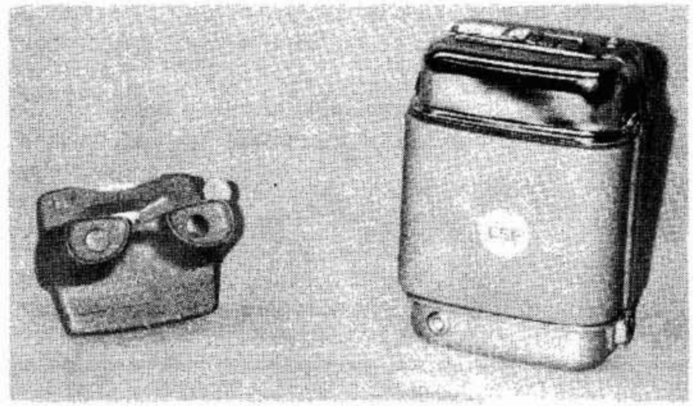


Figure 12.—PWSCSR with Viewmaster viewer and 3+3 reel.

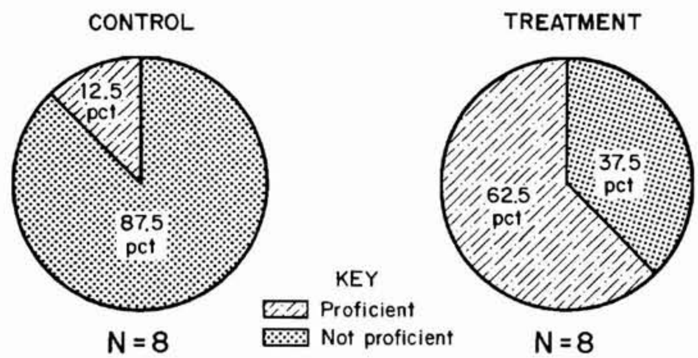


Figure 13.—Ninety-day donning proficiency on PWSCSR for trainees using the Viewmaster viewer.

Such a marked difference suggests mental practice holds much promise as a practical and simple mechanism for maintaining an acceptable level of SCSR donning skills between actual performance opportunities. Further research is needed to explore this possibility.

RECOMMENDATIONS FROM LESSONS LEARNED

First of all, there is no protocol for self-rescue, such as exists for mine rescue, that has made this function of oxygen-breathing devices nonproblematic. Whether or not workers can don and use SCSR's well enough to escape a fatally toxic mine atmosphere is still very much at issue, as indicated by recent Bureau interviews of 48 individuals who have escaped mine fires through smoke (*16*). The following recommendations are not, however, a suggestion that the industry initiate an SCSR training effort modeled after what is done to prepare people for use of mine rescue apparatus. Rather, they are based upon much empirical evidence that the original memorandum drawn up by NSC's Committee on Education and Training suggested a protocol that was not only workable, but that would have made SCSR donning proficiency a reality for most miners:

1. Only one procedure should be taught.
2. Training should be hands-on, with evaluation and feedback. The entire procedure ought to be taught and performed correctly, with no shortcuts.
3. Training ought to be conducted in-mine to avoid interrupting production and thereby introducing a distraction. Instruction should be done on a one-to-one basis in order to keep each miner's attention focused on the learning task.

4. Hands-on practice should be scheduled throughout the year. Training can be built into fire drills and other emergency preparedness routines.

5. Training models (or simulators) with easily cleaned and replaceable mouthpiece assemblies ought to be used.

6. Distributed mental rehearsals could be provided between hands-on practice sessions.

7. Trainers should sample their workforce periodically and do spot evaluations in order to keep track of proficiency levels. Remediation can then be given as needed.

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SUGGESTED ADDITIONAL READING AND VIEWING

In addition to those publications that have been cited in the report, there are various other materials that report, in-depth, results of the studies referred to in this overview. These documents, many of which are included in the next section, form a strong base for all recommendations listed here. An examination of the indicated materials, along with ones contained in the reference section, will suggest a possible and practical protocol for SCSR donning training and practice.

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