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A Profile of Workers' Experiences and Preparedness in Responding to Underground Mine Fires

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES

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Bruce Babbitt, Secretary

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Metric Units

cm	centimeter	L/min	liter per minute
h	hour	m	meter
km	kilometer	min	minute
kPa	kilopascal	t	metric ton

U.S. Customary Units

ft	foot	psi	pound per square inch
gpm	gallon per minute		

A PROFILE OF WORKERS' EXPERIENCES AND PREPAREDNESS IN RESPONDING TO UNDERGROUND MINE FIRES

By Charles Vaught,[1] Barbara Fotta,[2] William J. Wiehagen,[3] Ronald S. Conti,[4] and Richard S. Fowkes[5]

ABSTRACT

The purpose of this study was to determine mine workers' state of fire-fighting preparedness and the technology being used to detect and respond to underground coal mine fires. To investigate this problem, 214 underground coal miners were interviewed by U.S. Bureau of Mines researchers. Frequency distributions of workers' responses are presented in this report, along with segments of narrative accounts, to profile miners' fire-fighting capabilities. The data indicated that much variability exists from mine to mine and that there are several important changes operators may undertake in order to make miners better prepared to deal with fire underground: select appropriate sensors, establish and test a warning and communication protocol, construct a system capable of delivering hundreds of gallons of water per minute for sustained periods, institute formal fire preparedness audits, develop case studies of events that occur at an operation to use as teaching and assessment tools, and provide structured practice that can be incorporated into fire drills.

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INTRODUCTION

Historically, fires have been a leading threat to worker safety and to the productive capacity of coal mines in this country. During the 1960's and 1970's, approximately 50 fires per year were reported to Federal authorities. It is estimated that in each of those years another 200 nonreportable fires, lasting less than 30 min and involving no injury, also took place *(1)*.[6] Because such incidents were fairly common occurrences, a sizable portion of the industry had some experience in dealing with them. Additionally, these people shared a robust baseline of information that allowed them to assess improvements in fire safety over time. Then, between 1980 and 1990, there were, on average, 15 reportable mine fires per year (2). This figure represents a significant decline in both the number and incidence rates since the late 1970's. It also serves as evidence to the industry that efforts to improve fire protection have paid off up to this point.

A perception, voiced at the Mine Safety and Health Administration (MSHA) Mine Emergency Preparedness Conference, is that mine fires now verge upon the nonroutine *(3)*. This welcome reduction in mine fires presents several interesting considerations. First, people who are relatively new in underground mining may never have had to respond during a serious fire event. Such a condition may foster complacence. Second, those seeking to justify continued improvements in fire safety can draw upon fewer than one-third of the reported cases they would have had as examples two decades ago. Thus, their most readily available database has been eroded to the point that reportable fires will be less reliable as a dependent measure of effect. Any treatment, in the form of some widely adopted new technology, for instance, could not show a large reduction in the absolute number of mine fires reported each year because there are not that many to begin with. Yet, there are enormous potential social and economic costs accruing to any one of those fires that do occur annually.

That potential became reality at some operations during the past decade. The 1984 Wilberg disaster, near Orangeville, UT, claimed 27 lives. The permanent sealing of Beth Energy's Marianna Mine in 1988 and National Mines' Mathies operation in 1990 cost over 1,000 jobs in Washington County, PA. Added to these very real losses is the probability that millions of tons of high-quality coal will now go unrecovered. It should be clear that the capacity to detect and then safely extinguish an incipient mine fire is a critical one. This is a capability that ought to be developed and supported at all underground coal mines. Although few would argue against this need, it opens or suggests an interesting question: How does one measure this capability? Progress in "mine fire preparedness" implies an ability to measure gains over time, at both the minesite and aggregate levels. What levels of assessment are useful, for the individual minesite, to offer insightful information concerning fire prevention, detection, and response capabilities? There is evidence that capability can be equated with a readiness to act rapidly and effectively. For certain, quick response implies components of both people and technology.

Elapsed time between the onset of a fire and its detection is critical because fires tend to grow quickly in size and intensity (4). Although there is no clear official position on first response, some experts feel that ordinary workers will fight a fire regardless of whether they are really prepared to. As one miner put it:

> From what I understand, mine rescue is basically after the fact . . . What you really need is to do something before it gets to the point that you have to call mine rescue in. . . The biggest threat to our employment . . . has got to be fire.

In other words, many rank-and-file miners now believe that if fire strikes, their livelihoods are at stake. At any rate, it is these miners who are likely to be the first responders if a fire occurs at an operation. Since the first few hours are crucial, according to Mitchell (5), efforts of ordinary workers and front-line supervisors may actually have the best chance of preventing a mine from being sealed because of a fire. Though their role is pivotal, not much is known about how well the underground work force might be able to perform. The potential for making a fire situation worse, as a result of taking some type of action, is all the more reason for learning more about miners' fire-fighting preparedness. The exploratory study reported here discusses some technology that might give miners better warning and ability to fight fires, and then provides an assessment of such individuals' fire-fighting readiness.

Another issue, concerning the assessment of response capability, presents an interesting notion. A decline in the number of reportable fires is a gross indicator that allows experts to say something about the underground coal industry generally: There has been some improvement in overall mine fire preparedness. However, such an indicator is less reliable as a predictor of readiness at any particular operation. An indication of fire-fighting preparedness would have to be assessed from evidence gathered at the minesite. In other words, there are two levels from which to view the problem. On a general level, there has been significant improvement in the industry's fire

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

response capabilities over the past two decades. Specifically, however, few data have been gathered on a site-by-site basis to determine what improvements might be made on a local level. These improvements would move beyond regulatory compliance. It is expected that this report, based on data collected by the U.S. Bureau of Mines (USBM) at an array of underground coal mines in the United States, will help to focus attention on some central concerns involving this critical issue. This study is in support of the USBM mission to improve mine safety.

BACKGROUND

Fire Detection

When fire prevention fails, early detection and warning permit action to be taken in a mine while the blaze is in its incipient stage or still small. Over 70% of the fires that are detected within 15 min result in only light damage to a mine. Delays in detection have caused many fires to be sealed rather than controlled by direct attack (*5*). Such delays stem largely from the *way* fires are detected in most mines. Point-type heat detectors, for instance, are supposed to activate when ambient air temperature reaches some criterion level or when a certain rate of heat increase occurs. Small enclosed areas are where these detectors are best used. In a conveyor belt entry, though, the fire is likely to have grown significantly by the time a point-type heat detector activates an alarm. Other thermal sensors such as a distributed fiber optics system have shown promise for early warning (*6*). Carbon monoxide (CO) and point-type detectors are considered equivalent under Federal regulations (30 CFR, Part 75, Subpart L—Fire Protection) if installed according to MSHA specifications. CO detectors, however, could be more practical since CO is produced before flames erupt and does not generally decrease with distance unless it is diluted by an external flow of air, such as from another entry. Even so, a dependence on CO detection can be hampered by false alarms due to fumes, diesel exhaust gases, welding, cutting, or blasting.

Litton (*7*) discussed an approach that can be used with the present level of technology: Mine fire detection is done using CO and smoke detectors, both of which are product-of-combustion fire sensors. These sensors are designed to detect the CO and smoke from a smoldering or flaming fire carried in the mine ventilation entries. For fixed sensor alarm thresholds, very small fires may be detectable at low ventilation airflows. Fires would be much larger before they reached the same alarm level at higher airflows. The setting of alarm thresholds most often depends upon the mine background level of either CO or submicrometer particles. Alarm thresholds should be significantly higher than those background levels to protect against false alarms of the sensors (*8*). At the same time, however, sensors should not be too insensitive—that is, they should not have such high alarm thresholds they are incapable of detecting fires in their earlier stages of development.

Advances in sensor technology need to be made, especially for applications in diesel-operated mines where the diesel combustion products often overwhelm the fire products and cause detection systems to have a low level of reliability. Litton (*9*) described a novel fire detector developed by the USBM that can be used to discriminate between smoke produced by a fire and smoke produced by a diesel engine. The detector depends upon pyrolysis (chemical change brought about by the action of heat). This change occurs when a sample of smoke-laden gas passes through a short, heated tube. Inside the tube, fire smoke particles increase their number concentration and decrease their average size, while diesel smoke particles are unaffected. The detector is designed to be used in mines that have diesel-powered equipment, where the detection of fires is complicated because of the diesel emissions background levels of smoke and other products of combustion. A prototype pyrolysis fire detector was evaluated in a series of intermediate-scale tests, and its performance was very encouraging (*10*). With this device, the problems of false alarms of fire sensors due to diesel-produced combustion products can be reduced if not totally eliminated.

Laage, Pomroy, and Bartholomew (*11*) discussed USBM research aimed at developing a strategy to detect and locate mine fires in real time using a minimum of selectively placed sensors coupled with computer-aided data interpretation. The impetus for this work stemmed from the fact that it is impractical to install detectors at every desired location in an underground mine. The sheer size of a mine, including abandoned workings and unsafe locations, precludes sensor installations from both safety and economic standpoints. The net effect is that some fires are detected and located early, but the location of others, even if detected early, remains unknown too long for effective evacuation and fire fighting. Thus, an algorithm was developed to utilize the real-time outputs from a system of strategically placed underground detectors as inputs to a computer model for determining the location of an underground mine fire.

The algorithm involves three steps: instrumentation, computer simulation, and fire location determination.

Using the fire location algorithm, a hypothetical case study experiment was performed. The objective of the experiment was to determine whether detector locations could be selected that would produce a recognizable pattern of combustion product arrival times for every potential fire location and to determine if a slow-growing fire would adversely affect the performance of the differential arrival time algorithm. The subject of the experiment was a portion of the ventilation network from the Homestake gold mine in Lead, SD. Although the findings of this experiment were favorable, such an approach to mine ventilation and fire safety analysis is meant to supplement, not supplant, the traditional decision-making processes at a mine. The value of the fire location system is in the information it supplies to human decision makers.[7]

Fire Suppression and Control

Grannes *(12)* discussed USBM research that investigated the reliability of mine fire detection and suppression systems and the effectiveness of inspection and maintenance practices. There are two basic types of fire suppression systems, the automatic sprinkler type and the fire-sensor-actuated type. The former uses heat-activated sprinkler heads, each opening individually in response to fire. The latter uses fire sensors that activate a separate fire suppression system (water deluge or directed open water nozzles, high-expansion foam generators, dry chemical systems). Interviews with MSHA inspectors along with field data indicate that the reliability of mine fire suppression systems can be improved. Limitations of current inspection and maintenance practices were discussed. Predictive diagnostics methods were developed and tested in the field. The predictive diagnostics methods employ functional parameter measurement to predict wear-out-related failures in fire suppression systems. Using these techniques, an intermittent failure of an electrical relay system failure was diagnosed and corrected. An impending actuator failure was also noted. Limited field data indicate that the actual percentage of unreliable systems is somewhat greater or less than 25%. Reliability can be improved by careful adherence to standard maintenance and testing procedures and by applying preventive maintenance techniques.

When measures for preventing mine fires break down, something must be available to take over *(13)*. What is needed at this point is suitable fire-fighting equipment and personnel trained in its use. The sight of hand-operated fire extinguishers is commonplace in mines. Nonetheless, persons who have not had occasion to use an extinguisher may not know how to operate one effectively *(5)*. Hand extinguishers are most useful when fires are in their incipient stages. Extinguishers contain only a small amount of agent. Lack of knowledge in their use makes them of little utility and even dangerous since misuse on oil and other fluid fires can spread the blaze. Rock dust is effective in smothering fires, particularly in their incipient stages, if it can be shoveled or dumped by the sackful directly on the fire. Application with a high-pressure dusting machine has not been effective because much of the rock dust is wasted and the pressure needed to force the dust to the fire serves to fan the blaze. Chemical mobile units, despite their limited capacities, are useful if they can be moved to a fire sufficiently fast. However, water is by far the most useful and practical extinguisher once a fire has passed the incipient stage *(4-5)*.

Gallick discussed the one fire in 10,000 that occurs and is not easily extinguished but spreads to the roof or ribs of the mine, that is, an uncontrolled fire *(14)*. The equipment needed for extinguishing this type of fire is a system capable of delivering at least 190 L/min (50 gpm) of water at 345 kPa (50 psi) simultaneously to the end points of three or more fire hoses. This is a minimum amount, while realistically a system capable of delivering about 2,000 L/min (500 to 600 gpm) may be required. A portable hydrant solves the problems of getting the multiple hoses into action and preventing damage to the water lines from fire or roof falls, which will cut off the water supply. A portable hydrant is nothing more than a piece of pipe with an end cap and multiple outlets for fire hose hookups. Extended hose lines cause reduced performance because of friction losses, so separate large-diameter supply line hose that reduces friction loss should be available for installation. Once the fire-fighting equipment is in place, water may be needed to be placed on (1) fires covered by roof falls (cool by using sprinklers or a probe), (2) stoppings to keep them cool (use a water hose and a spray nozzle), and/or (3) inby areas after the fire starts (spray bars may be set up to help slow its spread).

Herbert *(15)* discussed methods of controlling or suppressing fires other than by direct attack: ventilation manipulation, fire-fighting foams, inert gas usage, and sealing methods. Ventilation manipulation consists of preventing air from continuing to reach the site of the fire. The use of high-expansion foam to control underground mine fires has been more recently studied by Conti *(16-17)*. The results of controlled, in-mine tests in the use of foam have met with some success. Another indirect method of fire suppression involves the dispersement of inert gas. With this method, nitrogen, an inert gas, has been used successfully, on occasion, to control mine fires *(18)*. Pump packing, a sealing method, has also been used to prevent and reduce the risk of spontaneous combustion of coal. This method involves the use of cement-like

[7]A discussion of fire warning systems is outside the scope of this document. The authors recognize that these systems constitute a critical but weak link in overall fire response activity.

materials that have a capacity for absorbing many times their own volume of water and then setting hard. The common method of dealing with open fires is often that of sealing off a main entry. Materials used for temporary seals include cement block, lumber, brattice, cloth, and tile or brick. Sometimes the location and magnitude of the fire make sealing underground inadvisable while sealing of surface openings is more feasible.

Mitchell and Nagy (*19*) offered explanations as to why some fires reach major proportions and require sealing for control. Their statistics show there is a 50-50 chance that unless a mine fire is extinguished within a few minutes, it cannot be dealt with in less than 8 h. Fire finds abundant fuel in many combustibles needed for mining, in addition to the coal itself, namely, insulation on cables, hydraulic oils, lubricants, tires, brattice cloth, belts, and wooden supports. As the flame consumes these fuels, its intensity increases, the temperature of the surrounding coal is raised, and volatiles are released into the mine atmosphere. These reactions may take minutes or hours. However, should the volatiles be ignited, the fire flashes, engulfs the passageways, and creates an inferno. Once developed, fire can spread rapidly. Miners must contend not only with the intense heat but with an atmosphere that is opaque because of black smoke containing toxic and flammable gases and with falling ribs and roof. A developed fire burns into and spreads on the ribs of coal pillars, generally near the roof. Most roof in mines falls when exposed to excessive heat, which results in fire burning beneath a fall of roof. These deep-seated fires can lie smoldering for long periods of time and then flare up again if air reaches the smoldering zone. Given such a scenario, the chance that the mine or at least a portion of it will have to be sealed is 1 in 20.

Training

The International Society of Fire Service Instructors (ISFSI) developed performance standards for the fire defense and suppression training of employees (*20*). The goal of a general fire defense training program at the "Employee—Fire Awareness" level is to ensure that employees are provided with the minimum education and training to allow them to (1) detect and recognize the presence of a fire emergency, (2) notify the proper authorities, (3) initiate evacuation, and (4) perform fire defense duties to defend themselves or their evacuation route from the fire. To achieve the training program goal, students must be able to demonstrate competency in the following elements: (1) know their duties and responsibilities in the event of a fire, (2) be able to recognize and detect a fire emergency within the work environment, (3) have a basic understanding of hazards and the role they play with regard to fire defense duties, (4) have a basic understanding of the role that each of the components of the fire safety system plays with respect to fire control and fire defense duties, (5) identify the common fire-extinguishing agents, (6) explain the operation of a common portable type of fire extinguisher, (7) have a thorough understanding of personnel safety aspects while performing the fire defense duties assigned to persons at the Employee—Fire Awareness level, (8) explain the fire attack techniques used with a common portable fire extinguisher, (9) explain the purpose of automatic fire detection, (10) explain the purpose of automatic sprinkler protection, (11) explain the purpose of a fire protection water supply system, and (12) explain the purpose of special extinguishing systems.

Standards that address the minimum general and onsite performance requirements for the fire suppression training and education portion of the integrated training program for industrial emergency response teams go beyond those listed above. The goal of a general fire suppression training program is to ensure that the industrial emergency responder students are provided with the minimum education and training to allow safe performance of either offensive or defensive fire suppression duties using portable fire extinguishers from outside the hot zone, to attack and/or control incipient or beginning fires. The students must be able to satisfactorily complete modules that require them to explain, list, or demonstrate competencies in the following: (1) duties and responsibilities, (2) chemistry and behavior of fire, (3) hazards, (4) fire safety concepts, (5) extinguishing agents, (6) portable fire extinguishers, (7) safety, (8) fire attack techniques, (9) automatic fire detection, (10) automatic sprinkler detection, (11) fire protection water supplies, and (12) special extinguishing systems. Details are given for each module of what the student is expected to explain, list, or demonstrate.

The National Fire Protection Association (NFPA) "Standard for Fire Prevention and Control in Underground Bituminous Coal Mines" (*13*) states that training should include annual instruction in fire prevention, fire-fighting techniques, and emergency evacuation procedures for all operating employees. According to the NFPA (*13*), fire drills, complete with activation of the mine warning system, should be performed frequently. These exercises would reinforce the training and help to identify weaknesses in a mine's emergency plan. As Mitchell (*5*) stated, "The best facilities and equipment can never compensate for poor preparation." Hence training is needed, and "the most important facts to teach and learn are how to lead and how to follow. Too often the section foreman is not the only one telling the crew what best to do ..." The drills should be unannounced and should involve a simulated fire or explosion specific to conditions in the section.

Gallick (*17*) argued that the training needed to fight a mine fire, like the equipment, depends on the extent of the fire. The general fire drill training that MSHA requires to be given to all employees, in Gallick's opinion, provides adequate basic training. This raises a few questions, however. Do all miners get the same basic training, or is there variability within and among sites? What can be learned from underground miners regarding their experiences in responding to smoke and fire underground? USBM researchers interviewed 214 miners from 7 coal mines to determine their state of preparedness and the current technology they use to detect and respond to underground mine fires. A profile of their basic readiness to respond is discussed in the sections that follow.

STUDY SETTINGS AND METHODOLOGY

SELECTION OF MINES

The selection of the seven mines included in the study was based on the researchers' former contacts with mine management. The study included an escorted tour of both the surface facilities and the underground mine conducted by either the safety officer or a supervisory staff person. Approximately 30 workers at each minesite answered a series of prepared questions (see appendix A).

A brief description of each of the minesites is provided in the following section and summarized in table 1. It can be seen that these operations varied by geographic location and mine size (based on the number of employees). All operations were mining coal seams 1.8 m (6 ft) or more high. The descriptions are intentionally nonspecific in order to maintain the anonymity of the seven participating sites. They shall be referred to in this report as mines A through G.

Mine A is a small (about 40 employees) nonunion operation in the Eastern United States that mines the Sewickley Seam, a high-volatile bituminous coal. Mine A uses continuous mining methods and produces 226,000 t of coal per year. Coal is transported from the sections to the surface via 3 km of haulage belt. Battery-operated track vehicles are the major mode of transportation for personnel and supplies. The mine employs thermal sensors for fire detection and a deluge water suppression system for belt drive areas. The mine has no unusual problems.

Mine B is a union mine located in the Eastern United States. It employs over 250 individuals. Using continuous miners and a longwall section, this mine extracts over 2 million t of clean coal annually from the Jawbone Coalbed, a high-volatile bituminous coal. Coal is transported from working sections via conveyor belt. Personnel are transported by track haulage. The mine is currently using a CO monitoring system and a deluge water suppression system, and it is also evaluating smoke sensors. Mine B experiences methane problems and has extremely weak roof and ribs. This mine also experienced a major fire since opening.

Mine C is a union mine located in the Eastern United States that extracts the Pittsburgh Seam, a high-volatile bituminous coal. The mine, which employs over 350 workers, is primarily a longwall operation, utilizing a 4-entry system and bleederless ventilation system. Mine C has an annual coal production of over 1,360,000 t. Track locomotives, mantrips, and jeeps are the major modes of transportation. The mine's coal haulage system consists of 107-cm-wide rubber and polyvinyl chloride (PVC) conveyor belting, which extends from the faces to the bottom where a dump bin is located. From there, mine cars are loaded and coal is transported out of the mine via a trolley haulage system. CO and thermal sensors are used for fire monitoring, and a deluge system is used for fire suppression at belt drives. The mine has no unusual problems.

Mine D is a union mine located in the Midwest. This operation mines the No. 9 Seam, a high-volatile bituminous coal. An elevator car and track equipment are the main modes of transportation at the minesite. Mine D has a work force of over 350 employees and operates 6 continuous miner units that produce 2,270,000 t of coal per year. The mine's coal haulage system consists of more than 13 km of rubber conveyor belting. The mine has a history of weak roof due to geological disturbances and, as a result, utilizes roof trusses installed in-cycle to provide safer working conditions. CO sensors are used for fire monitoring, and a sprinkler system is used for fire suppression at belt drive areas.

Mine E is a nonunion slope mine located in the Western United States. This mine extracts coal from the Upper and Lower O'Connor Seams, both high-volatile bituminous coals. Diesel jeeps are the main mode of transportation for personnel and supplies. With a work force of over 400 employees, this operation mines 5 million t per year using both continuous miners and longwall units. The mine's coal haulage system consists of over 4.6 km of 122- and 137-cm-wide rubber conveyor belting. CO and thermal sensors are used for fire monitoring, and automatic sprinklers are used for fire suppression in belt drive areas. The coal at this mine is susceptible to spontaneous combustion.

Mine F is a union mine located in the Midwest. Employing over 500 workers, this mine extracts coal from the Herrin Seam, a high-volatile bituminous coal known for its low ash and sulfur content. Continuous mining units are used in a room-and-pillar type of operation to yield an annual coal production of over 2,700,000 t. Track haulage

Table 1.—Mine descriptions

Mine	Geographic location	Number of employees	Union	Annual production, t	Type of mining	Type of fire detection	Type of fire suppression
A . .	East	40	No	226,000	Continuous	Thermal sensors	Water deluge system.
B . .	East	250	Yes	2,000,007	Continuous and longwall	CO sensors	Do.
C . .	East	350	Yes	1,360,000	Longwall	CO and thermal sensors	Do.
D . .	Midwest .	350	Yes	2,270,000	Continuous	CO sensors	Sprinkler system
E . .	West	400	No	5,000,000	Continuous and longwall	CO and thermal sensors	Do.
F . .	Midwest .	500	Yes	2,000,000	Continuous	CO sensors	Do.
G . .	West	225	No	4,350,000	Longwall	CO sensors	Do.

Do. Same as above.

is the main mode of transportation. Mine F's fire preparedness program includes six fully equipped fire brigade teams consisting of eight members per team. There are three teams on the surface and three teams underground at this operation. The mine also has well-equipped trailers located on the surface, for the fire brigade and mine rescue teams, and an intense fire training program. CO sensors are used for fire monitoring, and automatic sprinkler systems are used for fire suppression at conveyor belt drives.

Mine G is a nonunion operation located in the Western United States. This mine uses continuous and longwall mining to extract the Wadge Seam, a high-volatile C bituminous coal. Mine G is a slope mine that utilizes diesel jeeps and trucks as the major modes of transportation. The mine has a work force of 225 employees and mines 4,350,000 t per year. Mine G experiences air slack, a process in which the coal disintegrates because of rapid changes in mine conditions (air movement and temperature changes). These rapid changes cause the surface moisture of the coal to evaporate more rapidly than the interior moisture replacement, causing the coal to fracture and disintegrate. As a result, the roof and ribs of the entire mine are wire meshed and bolted. In addition to having the floors of all belt drive areas cemented, the roof and ribs in the main drive area are also gunnited (coated with a cementatious sealant) and washed down frequently. The haulage system of mine G consists of 11 km of 137- and 152-cm-rubber belting. On longwall panels, the mine uses three entries and a bleeder system. CO sensors are used for fire monitoring. An automatic sprinkler system, with signal feeds back to a surface mine monitoring control room, is used for fire suppression at belt drives. The coal at this mine is susceptible to spontaneous combustion.

SELECTION OF MINERS AND INTERVIEW PROTOCOL

Where mine size allowed, the sections in which interviews would be conducted were chosen randomly. For this exploratory study, an attempt was made to interview 30 miners at each minesite. The workers constituted a sample of convenience. The actual number varied slightly, ranging from 27 to 35. These data, along with general demographic information, are provided in table 2. A standardized interview guide (appendix A), which included both forced-choice and open-ended questions, was administered. All interviews were voluntary and were conducted one-on-one. Each interview began with a standardized introduction assuring the miner of the confidentiality of the responses. To ensure that all responses were entered accurately, miners were asked for their permission to record the interview. All but a few of the 214 miners interviewed agreed to have their accounts recorded. Interviews lasted approximately 20 to 60 min depending on the length of each miner's responses to open-ended questions.

Table 2.—Summary of demographic information for miners overall and mines A through G

Mine	Number interviewed	Ratio of females to males	Av age	Av years mining experience	Av years in job classification
A	27	0/27	38.4	14.6	7.6
B	30	1/29	39.6	16.8	7.5
C	28	0/28	43.6	18.8	9.1
D	33	0/33	38.6	16.0	8.1
E	31	1/30	33.5	6.1	2.4
F	35	4/31	37.8	13.9	7.1
G	30	1/29	39.8	14.4	7.2
Total or wt av. .	214	7/207	38.7	14.3	7.0

In most cases, the interviews were conducted underground, at the miners' normal work locations. The section foreman arranged for individual workers to be available to researchers, depending on the type of tasks miners were engaged in on that section at the time. A few of the interviews were conducted at surface facilities of the underground mine either just prior to or at the conclusion of a working shift. Accounts were gathered during both the morning and afternoon shifts. In most cases, two researchers would collect data at a particular minesite, each investigator traveling to a different location within the mine. Overall, the interviews took approximately 2 days to complete at each operation.

ANALYSIS OF THE DATA

Table 2 presents averaged demographic data. Included are the number of respondents at each mine, including the ratio of females to males, their mean age, years of mining experience, and length of time in their current job classification. As expected, there was variability across operations, although mines C and E account for the greatest departures from the mean. Mine C, a large eastern longwall operation, provided a sample whose mean age (43.6) was some 10 years more than the average age of those sampled at mine E, a western site that also has a longwall. The difference in mining experience was almost 13 years (18.8 versus 6.1), and perhaps not surprisingly, workers interviewed at mine C had roughly 7 more years in their present job classification than did the sample from mine E. Respondents from the other five sites fell between these two extremes, and the differences among them were less than 3 years on all three demographic variables.

The remote location and potentially dangerous nature of underground mines require workers to have higher levels of both routine and nonroutine task proficiency than might be found in the general industrial work force. To help profile these competencies, miners were asked to report any training or practical capabilities they had in the following categories: (1) technical mining skills (e.g., as fireboss, foreman), (2) specialized, emergency medical technician (EMT), training to assist injury victims in need of advanced first aid, and paramedic, (3) mine rescue team training, (4) training in fire fighting (military, volunteer firefighter, mine fire brigade), and (5) training to support the function of health and safety committee members.

Table 3 presents a mine-by-mine summary of the percentage of workers who reported special training, certification, or routine performance of tasks associated with the listed positions. Overall, the miners interviewed were most likely to have had training or certification in first-aid skills (54%), as a fireboss or mine examiner (37%), or as a foreman or manager (35%). From mine to mine, the proportion having skills in any particular category varied considerably. Across operations for most of the 11 areas listed, percentages for mine C, which had the oldest and most experienced workers, were among the lowest. The two exceptions at mine C were mine fire brigade and first-aid training. Here, percentages exceeded those for the overall grouping. Percentages at mine G were among the highest, particularly for first-aid training, reported by 90% of the miners compared with 54% reported overall. Percentages for mine G consistently exceeded those for the overall grouping in each category. It is interesting to note that miners at mine G had less experience than workers at four of the other mines.

PREPAREDNESS TO EVACUATE

Fire affects a significant proportion of underground coal miners at some time during their work lives. For instance, 180 of the respondents were asked if they had ever been notified to evacuate a mine because of fire. As figure 1 shows, almost 40% of those questioned responded in the affirmative:

> That's been—well, a long time ago. They had a cutting machine caught on fire, but it's been several years ago. I don't know how long ago it was. They evacuated us for that.

> Yeah, it happened one time down here, and that was just a few months ago. That was probably back in December. We had a hot spot back in our return... It was producing smoke, and they immediately shut the mine down...

Table 3.—Percentage of miners self-reporting special training, certification, or routine performance of certain tasks

	A	B	C	D	E	F	G	Av
Technical mining skills:								
Fireboss or mine examiner	26	33	7	18	58	60	53	37
Foreman or manager	44	43	11	21	29	43	50	35
Training in injury assistance:								
First aid	44	30	68	39	45	60	90	54
EMT	37	23	4	15	10	14	27	18
Ambulance or rescue squad	7	3	4	12	13	9	17	9
Paramedic	0	0	0	0	0	0	0	0
Mine rescue	15	7	7	27	13	9	37	16
Training in fire fighting:								
Mine fire brigade	15	3	14	12	3	14	17	11
Military fire fighting	0	10	4	3	6	6	7	5
Volunteer firefighter	7	10	11	24	19	11	17	15
Safety committee	4	23	7	6	10	11	20	12
Other certification.	7	7	4	3	3	0	30	8

The proportion of respondents who have had to evacuate because of a fire ranged from slightly less than one-fifth at mine E, which had a younger and less experienced work force, to approximately two-thirds for mines F and G.

Considering such a potential for fire underground, it is important that miners know their escape routes and mine evacuation plans. Workers were therefore asked when they had last walked their escapeways. The percentages of miners who reported having walked their escapeways within the past year are depicted in figure 2. The remainder either reported having walked their escapeways over a year ago or having never walked them, or could not remember when they had last walked their escapeways. Note that over 90% of the workers at mines A, C, E, and G reported having walked their escapeways sometime during the previous year. For the remaining three mines (B, D, and F) this percentage was less than 70%. Although rotational assignments for walking escapeways are required by regulation, it seems likely that four of the mines had such an actual practice in place, while the other three did not.

Miners were also asked when their crew had last participated in a fire drill. Answers to this question suggest that in at least some of the operations, fire drills were less than rigorous exercises:

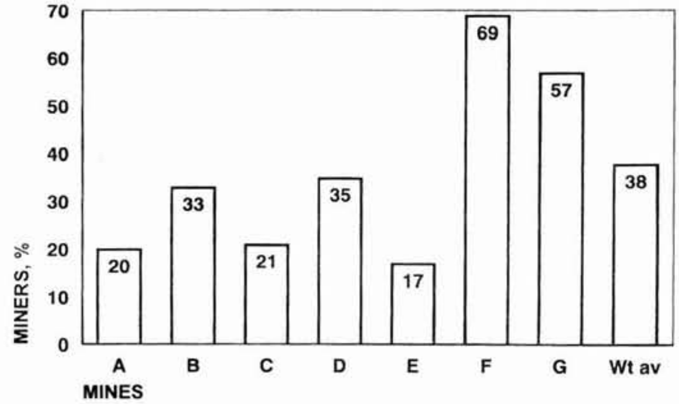
> From time to time some foreman would come in, and after they'd shut the face, they would [announce] "I've discovered a fire here." And we'd walk through a simulated-type drill. Just basically like I said, get to the phone, get to the fire box—nothing to really fine act—not too much realism involved either. I would say most people are pretty reluctant to participate. It's been awhile...
>
> Oh, just Monday. I don't know what you'd call it—a fire drill or [what]. They got a paper they read down the steps taken in case of a fire. You know, your secondary escapeways, your neutral and your primaries, your intake. We don't, I mean, we didn't actually go through a drill, "Hey, there's a fire... Let's do something!"

The responses for each mine are summarized as cumulative percentages in figure 3. Values for the past 3 months ranged from a low of approximately 25% for mine B to a high of about 85% for mine G. Overall, slightly less than 80% of the respondents reported participating in a fire drill at any time during the previous 12 months.

EXPERIENCE WITH INCIPIENT FIRE

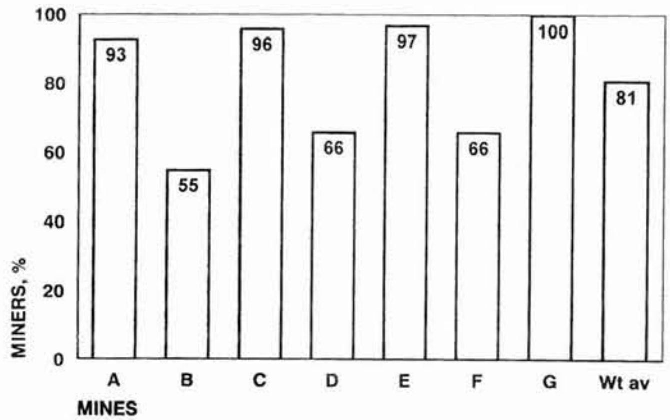
An interesting, although imprecise, indicator of encounters with fire is whether a miner was ever required to don a filter self-rescuer (FSR) or self-contained self-rescuer (SCSR) in an emergency. As illustrated in figure 4, a sizable

Figure 1



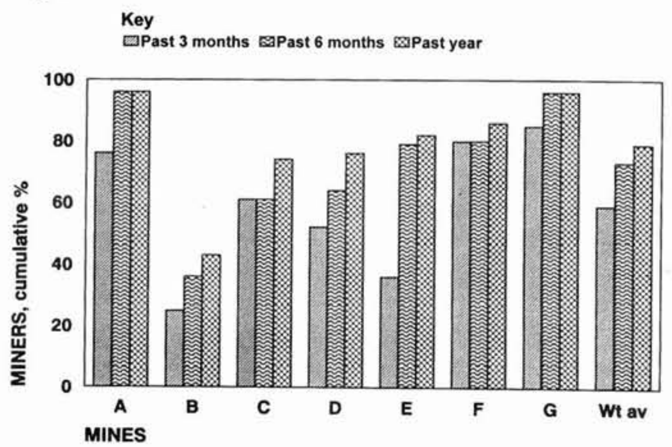
Percentage of miners notified to evacuate the mine because of a fire.

Figure 2



Percentage of miners walking escapeways.

Figure 3



Miners' last fire drill.

number of workers across operations said that they had done this at some time:

> Smoke came on up in the unit. I think we were about to head on out anyway. Some of us were riding the trip. I went ahead and put [my filter self-rescuer] on and we got out. It was a jeep battery on fire... It had a belt on top of it and it caught this belt on fire.

> The one time that I put the [self-contained] self-rescuer on was a battery fire. It was on the longwall section in a charging station. The batteries shorted inside. So we went down in there. We put the self-rescuers on, because it was—stunk real bad in the battery fire... There was smoke.

The actual percentages having donned apparatus ranged from a low of 11% at mine A to 31% at mine F.

If there are occasions when workers *must* don their emergency breathing apparatus, there are many more in which that potential exists. Table 4 summarizes for each mine the frequency with which miners reported seeing or smelling smoke underground *for any reason*. These frequencies varied widely from mine to mine. For example, at mines D, E, and F over 50% of the workers reported seeing or smelling smoke at least once a week, but only about 30% of those at mines C and G reported smoke this often. The two remaining operations (A and B) fell somewhere in between. It would appear, from looking at table 4, that smoke is a fact of life at most of the mines. In many instances, however, miners may well be aware of where the smoke is coming from and what is causing it.

Table 4.—Cumulative frequencies (in percent) with which miners reported either seeing or smelling smoke underground for any reason

Mine	A	B	C	D	E	F	G	Wt av
At least once per shift	4	7	4	18	16	20	7	11
At least once per week	37	37	32	[1]55	[1]55	[1]71	27	46
At least once per month	[1]63	[1]70	46	67	84	95	[1]67	[1]71
At least once per year	78	80	[1]89	79	100	97	90	88
Less than once per year	96	100	96	100		100	97	99
No response	100		100				100	100

[1]Median frequency for the mine

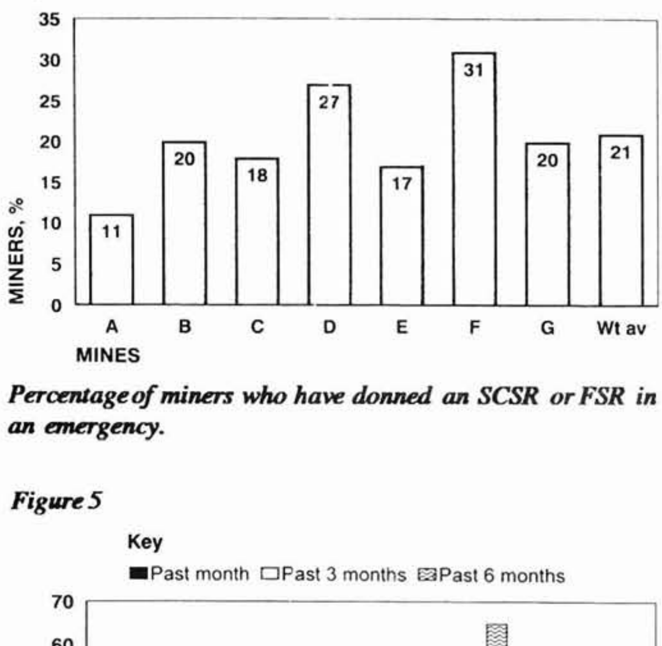
Workers were thus asked when they were last *caught off guard* by the sight or smell of smoke underground. Their responses are given in figure 5. The cumulative frequencies show that while less than 25% of the miners at mines A and D reported being caught off guard in the past 6 months, over 50% of the workers at mines C and F said they had been in the same period of time. As a followup to this question, miners were then asked what the source of smoke was determined to be:

> A couple of weeks ago...I smelled something that we didn't normally smell, and we got to looking for it, to try to find out what it was, from the smell... and then a few minutes later we noticed the smoke. [A plug in the back of a sub had overheated.] I knocked the power on the sub, and let the foreman know about it.

These known origins are listed in figure 6 along with the number of miners reporting each one. The most commonly cited sources were belt rubbing and hot metal.

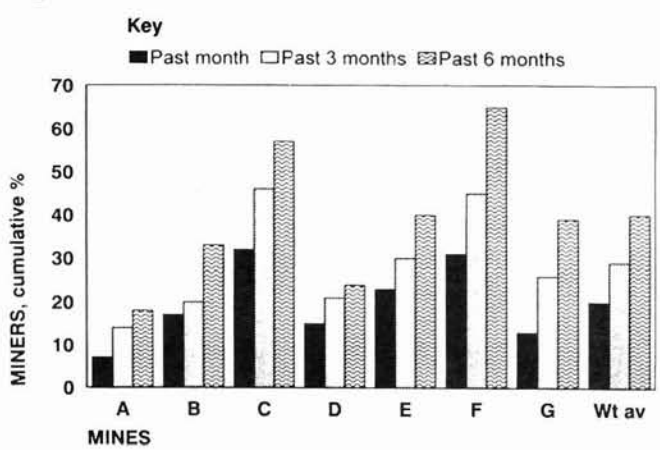
Of additional interest to investigators was how often miners were caught off guard by smoke that was not from a source on their section but rather had rolled in from some other location. Workers were thus asked about the last time they were caught off guard by smoke that had its

Figure 4



Percentage of miners who have donned an SCSR or FSR in an emergency.

Figure 5



Percentage of miners caught off guard by the sight or smell of smoke.

source at another location in their mine. Figure 7 is a bar graph categorizing how all of the 214 miners responded to this question:

> Yeah, about five years ago there was a roller on the belt—a big main roller. The belt had gotten jammed, and it was slipping inside the belt. Created a lot of smoke, and we was notified that there was a fire outby and we were to proceed to the evacuation area at once. The proper measures were taken at the time. Everybody was O.K. We used our self-contained rescuers at the time (I recall putting them on) until we got into the clear.

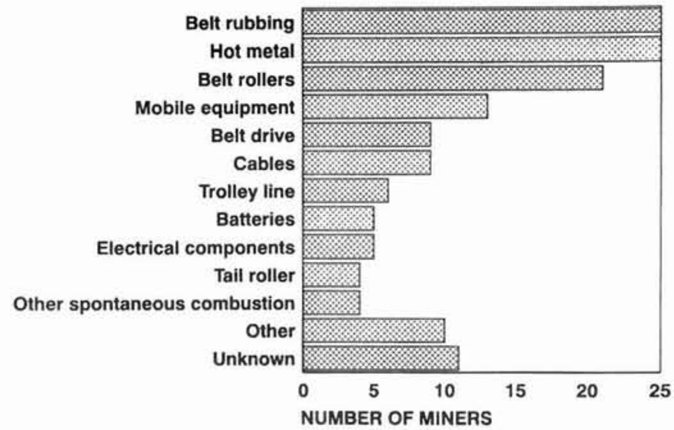
At least a third recounted that, sometime in the past, they had been caught off guard by smoke coming from somewhere off their section. In sum, while smoke may be a fact of life at most of the mines in this study, its presence often comes as a surprise to workers. Sometimes, as discussed below, miners may be required to take action.

UNDERGROUND FIRE-FIGHTING EXPERIENCE

Figure 8 presents for each operation the percentages of workers who reported having direct experience in fighting underground mine fires at some point during their mining careers. Many individuals were involved in more than one fire-fighting incident, and the percentages of those are further differentiated for each site. Workers at mines C and F were involved in more fire-fighting occurrences than were reported by respondents at the other five mines. At mine C, 82% of the miners reported at least one fire-fighting incident, and about half of those (43%) reported being involved in two or more episodes. Those workers interviewed at mine C were also, on average, the oldest and most experienced miners among the seven groups. About 70% of mine F workers reported two or more incidents of fighting underground mine fires, and an additional 18% reported one event. Although individuals at mine E were among the youngest and least seasoned, the percentages showing their direct experience in fighting underground mine fires are not very different from those at mines A, B, and G (where workers were older and more experienced).

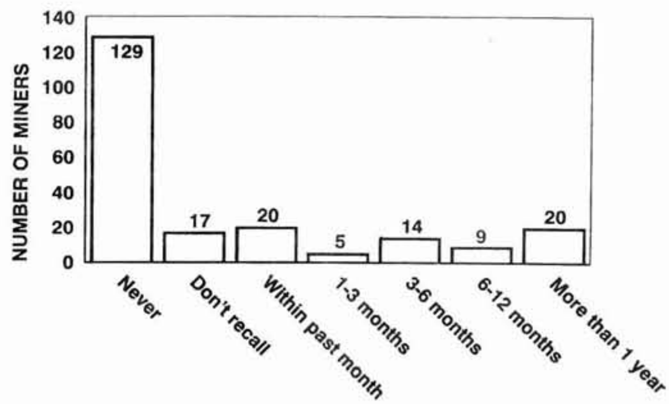
Followup questions were asked of the miners who reported being involved in an underground fire-fighting incident in order to gain additional information about their experiences and perceptions of the event(s). Across the seven mines, as illustrated in figure 9, 70% of the 214 miners reported being involved in at least one fire-fighting incident. About 20% of the workers were involved in episodes in which apparatus was donned to help fight the fire, and almost 15% were involved in incidents in which ventilation changes were made to help fight the fire.

Figure 6



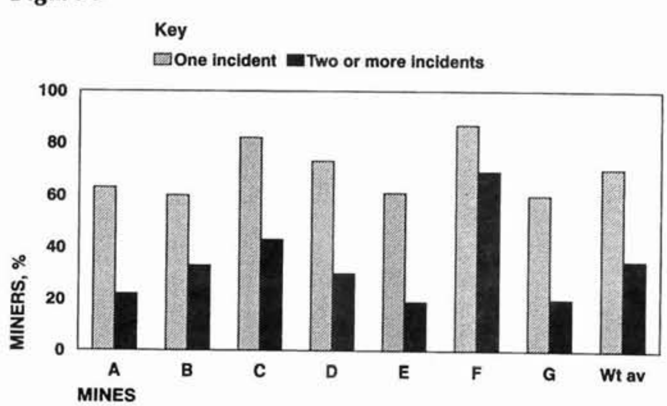
Source of fire for miners caught off guard.

Figure 7



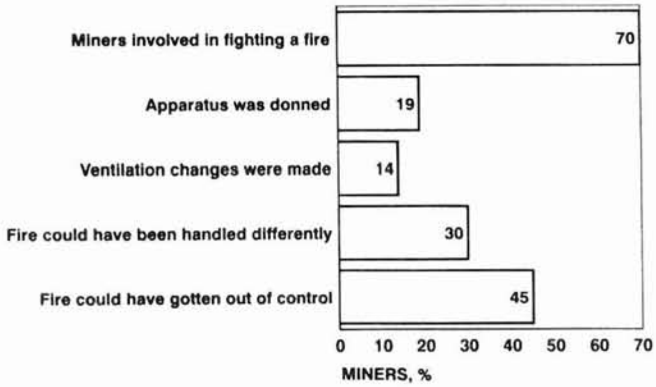
Last time source of smoke was not on miner's section.

Figure 8



Percentage of miners with direct experience in underground fire fighting.

Figure 9



Miners involved in fighting fires.

In terms of their perception of the way the fire was handled, 30% of miners reported being involved in at least one event in which they felt the fire could have been handled differently and 45% were involved in fighting a fire (or fires) that they felt could have gotten out of control.

Miners were asked a series of questions with respect to their experience in the use of fire-fighting equipment and materials (such as rock dust). The four bar charts in figure 10 summarize for each mine the percentage of those who reported having hands-on experience in the use of rock dust, fire extinguishers, fire hoses, and fire suppression systems on equipment. The extent of these workers' experience was differentiated as to whether they had used them underground to fight fires, used them underground for some other purpose, and/or used them at all. In the case of rock dust, however, the only relevant question seemed to be whether the miners had ever employed it to put out a fire underground.

A look across the four graphs and across mines, with regard to fighting fires underground, indicates that over half of the miners interviewed had hands-on experience using rock dust to put out a fire. In some instances, the attempt failed:

> I was on third shift rock dusting, and we was coming back up the track, and we hit smoke. There was me, and another rock duster, and a motorman. When we hit that smoke, we put our self-rescuers on to go through the smoke. He just put the motor in low tram and we rode the motor and rock duster through it. And when we got through it we got to the fire up there. We found it—located it, and we got on the good side; we had good air. We took our self-rescuers off then, and we had about half a tank of rock dust left. One of us went to the phone, to call and tell them about the fire, and I went in there, and started shooting rock dust on the fire. You know, trying to contain it, and it was done too far gone. And they called us out of the mine at that; after we fooled with it for a little while. They called us on out of the mine.

When fire extinguishers had been employed inside the mine, it was almost always to fight a fire. Forty percent of the respondents had used fire extinguishers to perform this task. About 30% of the workers had used water hoses to fight fire, and less than 10% had activated a fire suppression system for that purpose.

As a group, workers were most likely to report having hands-on experience in the use of water hoses (over 80%). Individuals were also most likely to have used hoses underground (about 75%). Since water hoses are utilized in the mine for such tasks as washing down equipment and wetting roadways, this is not an unexpected finding. Some 75% of all respondents had hands-on experience in the use of fire extinguishers, although only about half of these miners had used extinguishers underground. As mentioned above, most of the extinguishers discharged *inside the mine* were used on a fire:

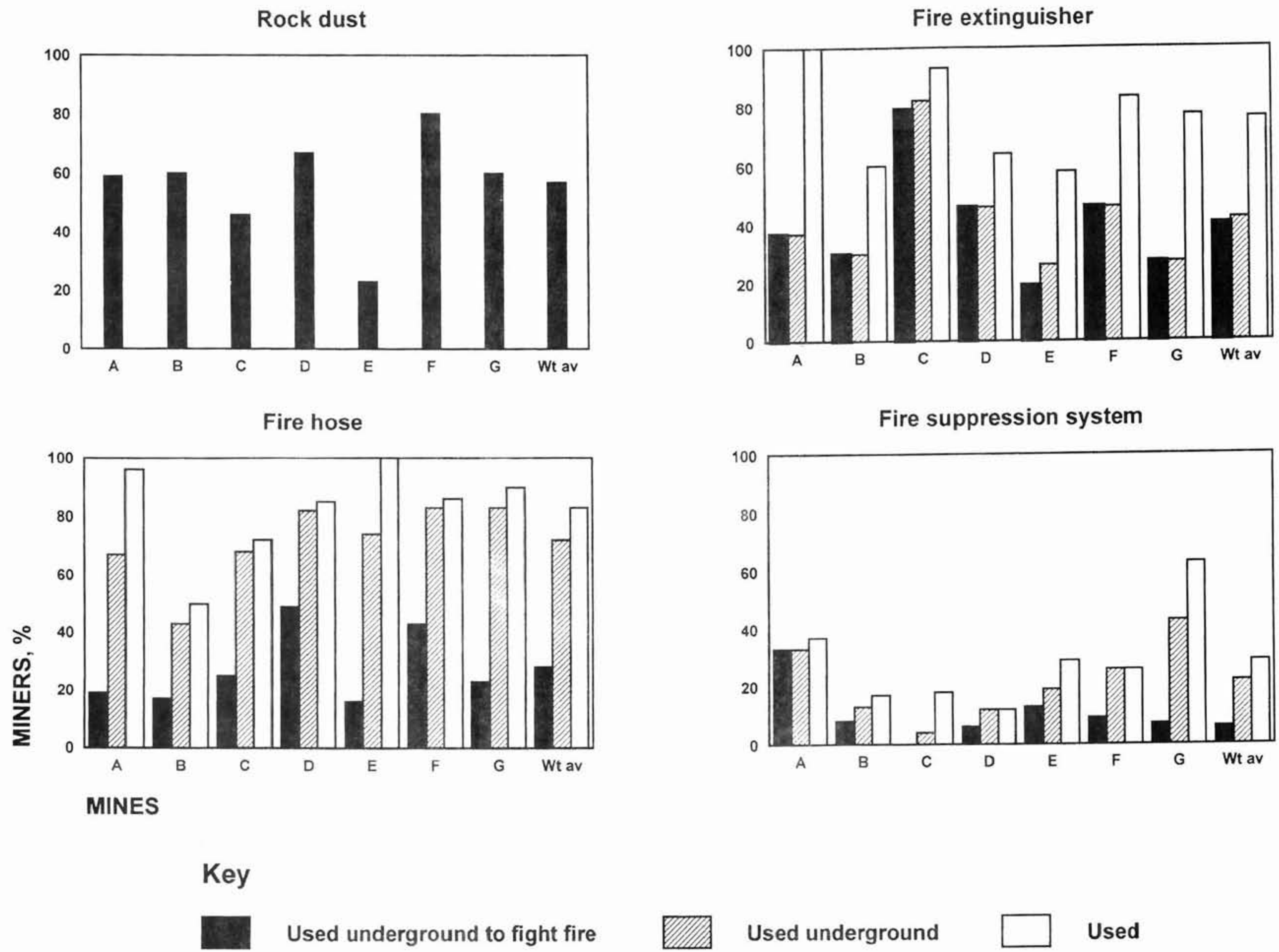
> I guess the [shuttle car] cable caught on fire. So anyway, the cable was burning. All the cable on the roll—probably about four blocks of cable on the roll was burning, and the shuttle car tire was on fire too ... Now, like I said, I went back in for the fire extinguisher. I shoot the fire extinguisher off; but it never helped.

In general, the lowest percentage of miners reported using a fire suppression system (less than 30% overall), with the exception of respondents at mine G, where more than 69% of the workers had activated a fire suppression system. In terms of the differences among mines with regard to workers' use of fire-fighting equipment, note that for mine A 100% of the miners had used a fire extinguisher and almost 100% of them had used a water hose. These individuals were also most likely to describe their fire-fighting training as a hands-on approach.

WORKERS' PERCEPTIONS OF TRAINING AND READINESS FOR FIRE FIGHTING

Miners were asked to describe their training to fight underground mine fires in terms of whether this instruction was

Figure 10



Percentage of miners reporting hands-on experience with various means of fire suppression.

conducted primarily through the use of lectures (being told what to do), discussion (talking about it), or a hands-on approach (practicing with fire-fighting equipment). Many miners reported that their training consisted of a combination of two of the three approaches (e.g., discussion and lecture). The percentages of miners reporting each of the three types of training are depicted for each mine in figure 11. Workers from mines B, C, D, and F described their training as consisting primarily of lecture and discussion. Conversely, more miners at mines A and E described their training as a hands-on approach. At mine G, this approach was often in combination with lecture and/or discussion.

Miners were asked if they felt they had an acceptable level of fire-fighting skills. Figure 12 displays the percentage of miners at each mine who felt they had an acceptable level of such skills:

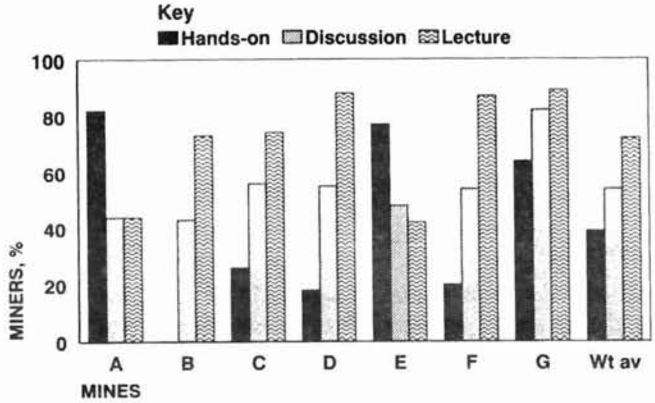
> I think I know when to fight a fire, and I believe I know how big a fire I can put out just by looking at it, and if I can't put it out then we're gonna get people down here to do it... If it's bad enough I can't put it out, management will be immediately made aware that we have a problem with this area.

At four of the mines, C, D, E, and F, about 70% of the workers felt they had an acceptable level of skills. The highest percentages were found at mines A and G, two operations where fairly high percentages of miners reported a hands-on approach to training. Conversely, only 57% of miners from mine B felt they had an acceptable level of fire-fighting skills; this was also the only mine where none of the miners described their fire-fighting training as a hands-on approach.

MINERS' PERCEPTIONS OF THEIR WORK CREWS AS FIRE-FIGHTING UNITS

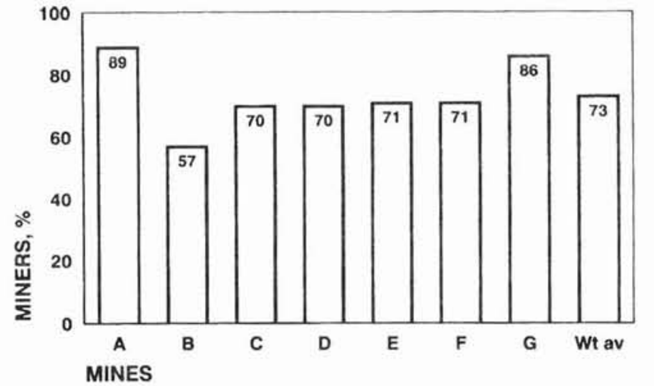
Figure 13 depicts the percentage of individuals at each of the seven mines who reported having specific duties if there is a fire on their section. These percentages vary from lows of 31% to 33% for mines G and C to highs of 74% to 94% for mines F, A, B, and D, respectively. Traditionally, many miners have been instructed (via lecture and discussion) in the performance of specific roles if a fire occurs. There appears to be a slight movement from these cultural traditions (e.g., mines G and C) to a more practical, problem-based solution that relies heavily upon the leadership, skills, and experience of the supervisor and veteran crew members. Obviously, there are both advantages and disadvantages to preassigning specific duties in case of an incipient fire. An important question might be whether or not miners actually put these preset protocols into place when fire does occur.

Figure 11



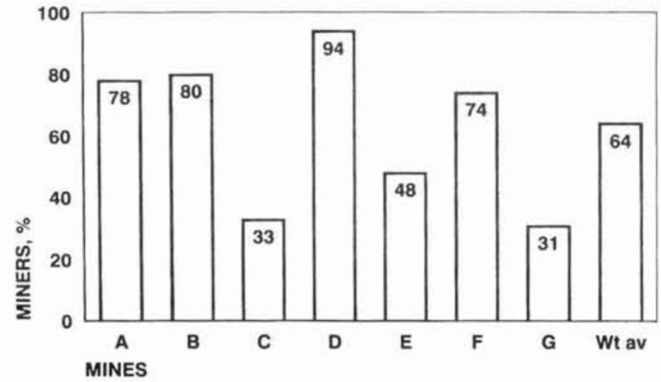
Mine-specific training in underground fire fighting.

Figure 12



Percentage of miners who feel they have an acceptable level of fire-fighting skills.

Figure 13



Percentage of miners reporting having specific duties if there is a fire on their section.

Miners were asked to rate, on a scale of 1 to 5, the confidence they have in their crew's ability to extinguish fires on the section:

> I think if it's extinguishable, we can put it out. [We couldn't handle] a fire that had been burning long enough that the ribs and stuff had also caught fire...

A mean confidence rating was computed for each mine by averaging the ratings of individual respondents. The resultant means, displayed in figure 14, range from a low of 3.9 for mine F to a high of 4.6 for mine A—again, the operation at which most miners had hands-on training.

SUGGESTED IMPROVEMENTS IN FIRE-FIGHTING PREPAREDNESS

One of the final questions interviewers asked 212 respondents (two miners didn't finish the interview) was what, in their opinion, could be done to improve fire-fighting response. Figure 15 shows that only 8% of the miners were satisfied with the fire-fighting training they were getting, and a portion of them called for less complacency and more involvement by the rank-and-file. Half of those individuals who felt that training at their operation was adequate were from mine A, which emphasized hands-on practice. Another 8% suggested that a formal discussion of techniques would be useful. One person even recommended that, in these formal discussions, management find a way to let workers draw upon their collective knowledge:

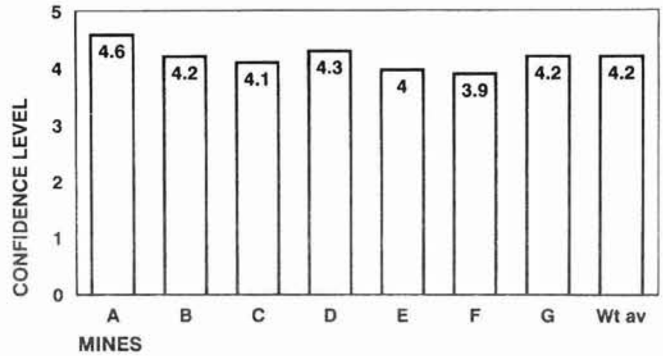
> Well, it might not hurt to have something once a month that was using all the experiences of every miner and what they had their biggest problem with and what they would have done to alleviate some [of the problem].

Seventy-two percent indicated a desire for hands-on experience, either in extinguishing a real fire or at least in handling fire-fighting equipment:

> I'd say either hold actual drills...or have...somebody up on top show you the proper use of a fire extinguisher... There are a lot of people don't know how to use them.

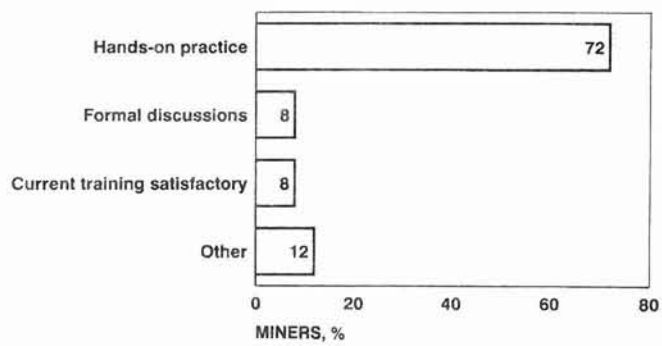
> I think if they went to hands-on training, or even a special class—like so many people at a time and just let them use a fire extinguisher. Let them experience high-expansion foam. A section of people, they know about the fire suppression systems on different pieces of equipment, but to actually activate it, I don't think there's too many people that's actually done it.

Figure 14



Confidence level of miners.

Figure 15



Training improvements.

One worker, who was a fire brigade member at his mine, carried the notion of what would constitute good hands-on training a step further:

> Start out with several individuals per unit. Teach them at least the basics, as far as putting on the air equipment, the bunker gear, give them just the basics of really being a fireman... And that's the key, as opposed to waiting 35 or 40 minutes for somebody else to show up. By that time it could be so far out of control that it can't be handled by anybody, I think.

In sum, most of the miners had apparently given some thought to ways in which the work force could become better prepared. Their suggestions ranged from such simple items as seeing for themselves where various fire-fighting equipment is located to full-scale drills underground using smoke generators.

In addition to identifying ways in which training could be enhanced, a substantial number of workers suggested organizational and technological improvements that needed to be made at their mine. Many of these items dealt with better communications, and they ranged from such things as developing a crew plan to cleaning signs regularly. Other concerns voiced by some of the respondents were perceived shortcomings in equipment availability or a lack of adequate water pressure at their operation. So, while the need for hands-on training was uppermost in the minds of those workers interviewed, several thought of ways to augment this instruction by improving the system.

DISCUSSIONS OF THE IMPLICATIONS

During the past 15 years the number of reportable mine fires has declined. Industry efforts to provide better fire protection have played a part in this trend. The number of mining jobs has also declined, partly because there are now fewer mines. It can be argued that this has brought about a change in people's thinking. Whereas workers might once have held the notion that if their mine were sealed because of a fire, they could go to work at another operation, they are now more likely to regard sealing as an end to a career in mining. Whereas miners might once have been reluctant to endanger themselves in a fire-fighting effort, they are now more likely to think in terms of saving the mine in order to save their jobs. Each incident that occurs, therefore, may be dealt with by a group of first responders intent on extinguishing the fire. It becomes critical to first understand their capabilities and then to enhance them where necessary. There are several important areas in which mine operators can undertake changes to make workers better prepared to deal with fire underground: detection and warning, suppression systems, preparedness audits, case studies, and structured practice.

Fire Detection and Warning

The first aspect of an enhanced fire response capability involves hardware. Since timeliness is key to a successful first response, strict attention must be paid to the selection of appropriate sensors, depending upon where they are to be located underground. It is likely that more than one type could be utilized. Additionally, an operation should have a preventive maintenance schedule in place to ensure that all detection and suppression devices work properly. Moreover, since early detection is of little value unless a quick response is mobilized, a mine ought to have an established warning and communication protocol that has been tested and refined as needed.

Fire Suppression System

Because water is the most practical extinguishing agent once a fire has passed its incipient phase, a well-prepared operation will have adequate quantities and pressure as well as the means to deliver it to a fire site. Such a system, realistically, would include such items as large-diameter supply lines, portable fire hydrants, and high-pressure hoses with suitable nozzles. Rather than the minimum 190 L/min (50 gpm), this system should be capable of delivering hundreds of gallons per minute for sustained periods of time. The implication here is that some thought must be given to water reserves.

Preparedness Audits

Insofar as the task of detecting and extinguishing a fire may require the involvement of a complex system, current USBM research is aimed at developing and testing formal fire preparedness audits. The chief advantage of such a strategy, using a carefully defined and preset protocol, is that any strengths and weaknesses of a site could be highlighted in some systematic way. In addition, there would be less chance that problem areas might go undiscovered and hence uncorrected.

"The best facilities and equipment can never compensate for poor preparation" (5). A large part of mine fire preparedness, therefore, is worker capability. And, a large part of worker capability is experience and training. One of the most interesting observations from the data, in terms of experience, is that 45% of these miners reported having dealt with a fire that could have gotten out of hand. Additionally, 30% of the respondents were involved in at least one incident they believed might better have been handled differently. It would seem from these statistics that while there are many successes, there is also room for improvement in how people respond to fires underground. A very interesting observation concerning training needs, in view of this fact, was made by the person who suggested companies find a way to let workers learn from others' experiences.

Case Studies

In a sense, each occurrence of fire underground, no matter how small, presents a teachable moment for the work force. Safety personnel should consider recording the particulars of these events in order to assess what was done correctly and where mistakes were made. Teaching points could then be derived and passed on in safety talks or embedded in fire drills. Thus, miners at an operation would be exposed to ongoing learning opportunities that draw upon things that have happened to people they know in their own work setting. Another use of such a compilation would be as a database to indicate, over time, whether improvements in worker responses were being achieved.

Structured Practice

A major drawback to learning fire response procedures "on-the-job" is the lack of structured practice. There are some aspects of fire preparedness that require cognitive knowledge and others that demand motor task skills. Safe evacuation, for instance, depends on knowledge of a mine's escapeways. Yet, at three of the sites in this sample, a sizable portion of those interviewed had not walked their escapeways within the past year. A successful attempt to put out a fire might well hinge upon the responder's having some skill in the use of a fire extinguisher. Many of the miners sampled, though, had used one only in an emergency. That is hardly the situation in which to learn good technique. However, the percentages of miners who had some fire response training as either volunteer firefighters or part of a mine fire brigade are perhaps reflective of firms' encouraging employees to expand upon skills that may be of direct, long-term benefit to both the work organization and the community.

It would seem, from the data gathered in this study, that there are two types of missed opportunities at some operations. On one hand, good fire drills not only could incorporate an opportunity to learn from the experiences of others through discussions or reenactments of past incidents but might provide a wide variety of hands-on experience in using emergency equipment as well. The better structured and planned these drills are, the more teaching can take place in a reasonable timeframe. On the other hand, occurrence of incipient fires provides opportunities to look back, evaluate, and enhance prevention, detection, and response capabilities.

Variability in Fire Preparedness

By and large, the picture that emerges from this study is one of variability. Significantly greater percentages of interviewees had walked their escapeways at some operations than at others. The same was true for those who recently participated in fire drills. The broad types of training offered to the work force also varied, with some mines relying heavily upon discussions and lectures as the main vehicle for developing fire response skills. Some mines tended to more formally integrate learning from their ongoing fire and smoke experience as a means for maintaining fire prevention, detection, and response communications with the work force. With little variability, all mines seemed to take the *threat* of smoke and fire seriously. However, the median frequency of reported smoke at three mines was at least once a week, while at one it was about once a year. The most consistent part of this picture is captured in figure 8. That is the graph showing the percentage of workers at each mine who have, at some time during their career, fought a fire underground. It suggests that fire is a constant.

There probably is no primary difference, during the incipient phase, between most fires that go unreported and one that results in a mine being sealed. It is simply that the latter either wasn't detected quickly enough or was not responded to properly. To achieve enhanced mine fire preparedness, mining companies will need to sharpen their strategy in relation to available technology and equipment while investing increased time and effort in their human resources. If this is done, the number of reportable incidents will likely decline even further and there should be even less chance of another disaster or permanent mine sealing.

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APPENDIX A.—INTERVIEW GUIDE

Interview guide - 3/17/92

Mine ____________________ Company ____________________

Interviewer ____________________ Date of Interview ____________________

Demographic Information

1)Identifier____________________

2) Age ______ 3) Sex _____ M _____ F 4) Years mining experience________

5)Job title ____________________ 6) Years of job experience__________

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

	Special Training	Certification	Routinely Perform
7) Foreman/manager	______	______	______
8) Safety committee	______	______	______
9) Mine rescue	______	______	______
10) Fireboss/mine examiner	______	______	______
11) Volunteer fire fighter	______	______	______
12) Mine fire brigade	______	______	______
13) Military fire fighting	______	______	______
14) Ambulance/rescue squad	______	______	______
15) First aid	______	______	______
16) EMT	______	______	______
17) Paramedic	______	______	______
18) Other (describe)__________	______	______	______

(turn recorder on)

Experience and Training in the Use of Breathing Apparatus

Have you ever donned a filter self-rescuer (FSR) or a self-contained self-rescuer (SCSR) in an emergency? Yes _____ No _____

If "yes" - No. of instances________ Date of last donning _________

Circumstances?____________________
(fill in after story)

When did you last receive training on the SCSR? Date _______ (or) No. of months ago ______

Familiarity with your mine's evacuation plan

Could you don your SCSR in the event of an emergency?

Yes____ No_____ Don't know______

Do you know where your escapeways are located? Yes ____ No ____
What entries are they?

When was the last time you walked your escapeways?__________

Never______(skip to next page) Don't recall________ (skip to next page)

Were you in the lead or did you follow other miners off the section?

Lead_____ Follow______

Did you walk all the way to the portal or just part of the way (eg. mouth of the section)?

About how long did it take you to walk the escapeway?

General Fire Experience Information

The presence of smoke on the working section does not always indicate a serious situation. Miners sometimes smell or see smoke that at times may be the result of planned maintenance activities such as the use of torches and welders.

1. FOR ANY REASON, how frequent would you estimate either smelling or seeing smoke underground?

a. once/shift ____ b. once/week_____ c. once/month_____ d. once/year_____ e. other _____

2. When was the last time you were *CAUGHT OFF GUARD* by eitherthe sight or smell of smoke underground?_______

Don't recall_______ (skip to next page) Never_________ (skip to next page)

Briefly, what was your reaction?

Did you notify anyone? Yes _____ No _____

Whom did you contact?

What was the source of the smoke (cable fire, welder, cutting torch, hot roller, etc.)?

3. About how many times over the past year would you estimate being *CAUGHT OFF GUARD* by the smell or sight of smoke underground?_____________

4. When was the last time that the source of the smoke was NOT on your section (immediate work area)? __________

Don't recall_______ Never______

5. When was the last time that you were notified that there was a fire underground and you may need to evacuate the mine?

Don't recall_______ Never______

Describe briefly:

Open-ended questions relating to fire fighting experience

(As a follow-up to the previous questions, ask the miner for specific details about his experience in fighting an underground mine fire. These details could relate to any fire regardless of the kind of fire (cable, roller, equipment, etc.) or size of the fire. The details should reflect the complete set of circumstances such as how the fire was spotted, the size of the fire, and the equipment/materials used to extinguish.)

Incident # 1.

What, if anything, could have been done differently?

Could the situation have gotten out of control?

Any apparatus donned? Any changes made to the mine ventilation?

Transcribe: Yes No

Incident #2.

What, if anything, could have been done differently?

Could the situation have gotten out of control?

Any apparatus donned? Any changes made to the mine ventilation?

Transcribe: Yes No

Use of fire fighting equipment and procedures

What kind of equipment is available for fire fighting in your normal work location?

Have you ever used a fire extinguisher underground? Yes _____ No _____
(If "yes", was it used to extinguish a fire?)

Did it extinguish the fire? Yes _____ No _____
(If "no", did it malfunction or was the fire too large, etc.)

Have you ever used the fire supression system on a piece of mining equipment? Yes ___ No ___

Did it extinguish the fire? Yes _____ No _____
(If "no", explain if it malfunctioned or if the fire was too large, etc.)

Have you ever used a water hose underground? Yes _____ No _____
(If "yes", was it used to extinguish a fire?)

Did it extinguish the fire? Yes _____ No _____
(If "no", explain if it malfunctioned or if the fire was too large, etc.)

Have you ever used rock dust to extinguish a fire? Yes ______ No ______
(If "yes", explain.) Did it extinguish the fire? Yes _____ No _____

(If "no", explain what happened - if the fire was too large, etc.)

Mine specific training in fire fighting

Describe your training in fighting underground mine fires.

Fire drills_____ Annual retraining_____ Other_____

When was the last time your work crew particpated in a fire drill?______________

What kinds of equipment are used in training?

Extinguishers Fire Hoses Foam Generators Fire suppression systems

other (explain)____________________

Which of these have you actually activated in practice or used on a real fire?

Extinguishers Fire Hoses Foam Generators Fire suppression systems

other (explain)____________________

During training, did you extinguish a real fire or simply demonstrate the use of fire fighting equipment?

Real fire Demonstration (If a real fire, what kind? How large?)

Where was this training conducted?

Which of the following best describes your training in fighting underground mine fires:

a. We talk about it.

b. We are told what to do in case of a fire.

c. We practice with fire fighting equipment.

Do you have any specific duties if there is a fire on your section? Yes_____ No______

What are they?

Who would be in charge of fire fighting efforts?

Do you feel that you have an acceptable level of fire fighting skills?

On a scale of 1 to 5 (with 5 being the best), how confident are you that your crew could extinguish fires on the section?

What type of fires do you think your work crew could not handle?

In your opinion, what could be done to improve fire fighting training?

If the miner indicated any advanced training in fire fighting, go on to the next section.

Fire Fighting Information

Summarize the type of specialized training from section 1.

Volunteer fireman______

Mine fire brigade_______

Have you ever fought a structure fire? Yes ____ No ____

What kind of structure(s)?

Is the fire fighting training and experience you have applicable to fighting firesunderground?

Yes ____ No ____ In part _______ (please explain below)

If the miner is a member of a mine fire brigade, go on to the next section.

Fire Brigade Information

How long have you been a member of the mine fire brigade? ____________________

How many people are on the fire brigade at your mine?_________

Does each shift have a fire brigade or is the brigade made up of miners from all shifts?

How are the brigade members selected?

Who is in charge of the fire brigade at your mine?

How is this person selected?

If this person is absent, who takes charge?

What type of equipment do you have available?

A. Personal protective equipment (ex. turnout gear, SCBA, etc.) -

Where is this equipment located?

Is this equipment adequate?

B. Physical fire fighting equipment -

Where is this equipment located?

Is this equipment adequate?

What kind of training have you completed as a fire brigade member? (describe below)

(at the mine site, ie. drills)

(off the mine site, ie. fire school training)

Is there cross training between members for various fire fighting duties? (Are fire brigade members trained for more than one fire fighting job)?

How often do you practice to maintain your fire fighting skills?____________________

Describe the type of training exercises used to help maintain fire fighting skills.

How often should you be retrained? ____________________

Describe the mustering plan (how the brigade is called) used in case of a fire.

When is the last time that your brigade was called into action?

Approximately how much time did it take to be fully prepared?

Have you ever fought a fire of any size or type in a coal mine? Yes ____ No ____

What type of fire was it?

What were your duties?

Type of breathing apparatus used?

What was used to fight the fire (e.g. water hose, extinguishers, etc.)?

What was the outcome of the fire you fought?

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