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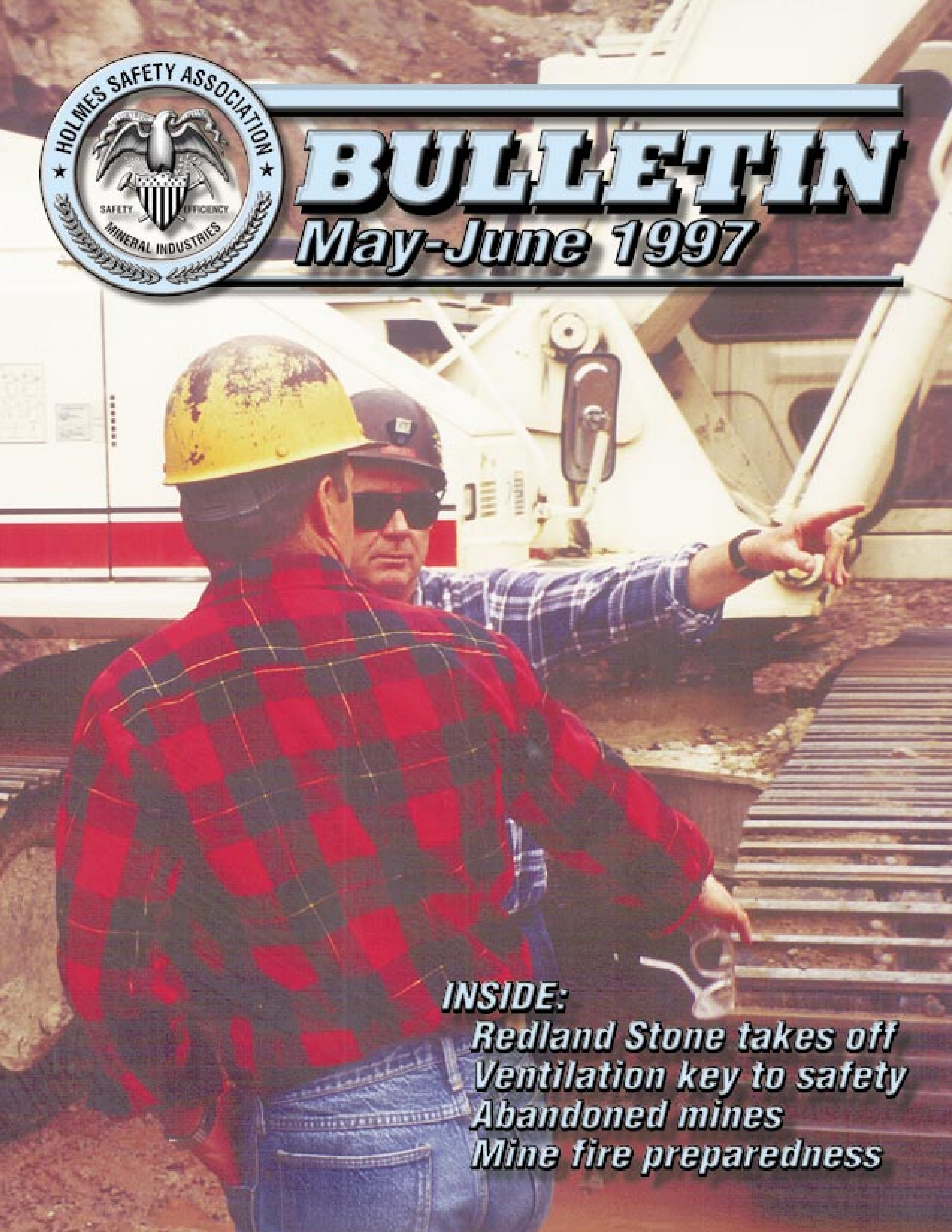

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Safety analysis of surface haulage accidents—Part 1

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Abstract

Research on improving haulage truck safety, started by the U.S. Bureau of Mines, is being continued by its successors. This two-part article reports the orientation of the renewed research efforts, beginning with an update on accident data analysis, the role of multiple causes in these accidents, and the search for practical methods for addressing the most important causes. Fatal haulage accidents most often involve loss of control or collisions caused by a variety of factors. Lost-time injuries most often involve sprains or strains to the back or multiple body areas, which can often be attributed to rough roads and the shocks of loading and unloading. Part II will describe research to reduce these accidents, including improved warning systems, shock isolation for drivers, encouraging seatbelt usage, and general improvements to system and task design.

Introduction

Although surface mining has always experienced lower accident rates than underground mining, and these rates have been generally improving, recent increases, particularly in the number of powered haulage accidents, have caused concern in the mining industry. As the most common type of machinery involved in surface accidents, haulage trucks have become the primary target for improving safety performance. This paper discusses the ongoing efforts by the successors to the U.S. Bureau of Mines (USBM) to analyze and solve haulage truck safety issues.

Ideally, accidents would not happen. Operating procedures would eliminate all possible hazards, and these procedures would always be followed. Equipment would be perfectly designed, flawlessly maintained, and never operated outside of design parameters. The worksite would be constant and predictable, introducing no hazards of its own. Unfortunately, this is an unattainable ideal—the realities of people, machinery, and the mining worksite are constantly pushing one or more of these conditions outside of the ideal. Understanding and controlling the causal factors in haulage accidents is essential to reducing their probability of occurring.

Accident causes and solutions

Most accident research now recognizes the role of multiple causes in accidents, including a significant human performance component. In the most detailed study of accident causes in mining, Sanders and Shaw (1988) studied underground mining accidents through an expert-panel investigative procedure. Their research showed that 88% of accidents had at least two major causes. This study also showed that "perceptual-cognitive-motor" errors (related to the more common term, "human error") were a causal factor in 93% of the accidents. While the effort and expense entailed in this type of analysis have so far precluded its use in surface mining, the general principles should be applicable. That is, attempting to identify a single cause for every accident is usually an oversimplification. Also, human performance and limitations will often come into play, even if other factors (poor design, dangerous conditions, etc.) essentially "forced" an error.

In surface haulage, human performance becomes a critical issue because of the unusual demands the vehicles place on their human operators:

- Roadways and work areas change frequently.
- The sheer mass of the trucks sometimes requires control inputs (e.g., braking) far in advance of the desired action.
- In large operations, the drive into and out of the pit is long and tedious.
- Rough roads and loading impacts can subject the driver to dangerous shocks and vibration.
- Visibility is sharply curtailed by the bulk of the vehicle.

Because of these demands, solutions to haulage truck safety problems must consider the human factors aspects of the task, even when engineering solutions seem most appropriate. The specific problems that need to be solved can be determined by studying the accidents involving haulage trucks.

Analytical approaches

Accident data analysis is an indispensable tool for understanding the causes of accidents. Systematic analysis of large numbers of accidents can reveal patterns and commonalities that might not be evident when looking at a single incident. The analysis can be based on industry-wide databases of accidents, in-depth analysis of official written accident reports, or data collected especially for the analysis. Each of these approaches has characteristic strengths and weaknesses.

Industry-wide databases

The most widely used source of U.S. mining accident information is the Mine Safety and Health Administration (MSHA) database collected from the quarterly 7000-1 and 7000-2 forms. In addition to reports published by the agency, the raw data is available from their Internet Web site (http://

www.msha.gov). This data is essentially a census of injuries in the U.S. mining industry, although it is conceivable that some accidents are not reported. The current study reports updated statistics from the MSHA database, bolstered by cost estimates from the USBM-developed Accident Cost Indicator model (ACIM) described in more detail below.

Textual analysis of official reports

In addition to the coded information about accidents, there is sometimes a written description available. For instance, accidents reported to MSHA on the 7000-1 form also have a brief description provided by the mining operation. Fatalities have a more detailed textual record in the form of an official accident investigation report. This textual information, because it is free of the constraints of the coding system, can incorporate details about the accident that might be missed otherwise. The fatality reports are particularly informative, containing details about the work procedures, equipment, victims, and even diagrams of the accident site. Unfortunately, this approach is not without its limitations. It is very time-consuming to convert the textual descriptions into a form useful for tabulating and comparing large numbers of accidents. Key information can be omitted unless the report writer is following a specified format. This process also requires subjective judgments that may be difficult to duplicate or validate.

This analytical approach was successfully applied to surface equipment accidents by Aldinger and Keran (1994) in an overview of the entire mining industry, and by Aldinger, Kenney, and Keran (1995) in a more detailed study of the coal segment of the industry. They employed a panel to categorize accidents based on the written narratives in the MSHA database. By using the narratives, they were free to develop categories of accidents that were more descriptive than the traditional categories. In their study of surface coal mining, Equipment Operation was the most common category of accident for haulage trucks (46.3%) followed by Ingress-egress (25.8%) and Maintenance (22.1%). Within the Equipment Operation accidents, the most common types were Jarring (37.7%) and Loss of Control (26.8%). The main Jarring categories were Rough Ground (44.5%), Loading Shock (33.5%), and Dumping Shock (15.5%). Loss of Control categories included Too Close to Edge (36.4%) and Runaway (27.3%). Figure 1 shows how these categories and subcategories are related.

Seatbelt usage is another area where the textual information reveals new accident details. While only 163 of the 2,720 accident reports studied

Figure 1.—Surface coal haulage truck accident categories in successively higher detail. Based on analysis of written accident descriptions for 1989-91 (Aldinger, Kenney, and Keran, 1995)

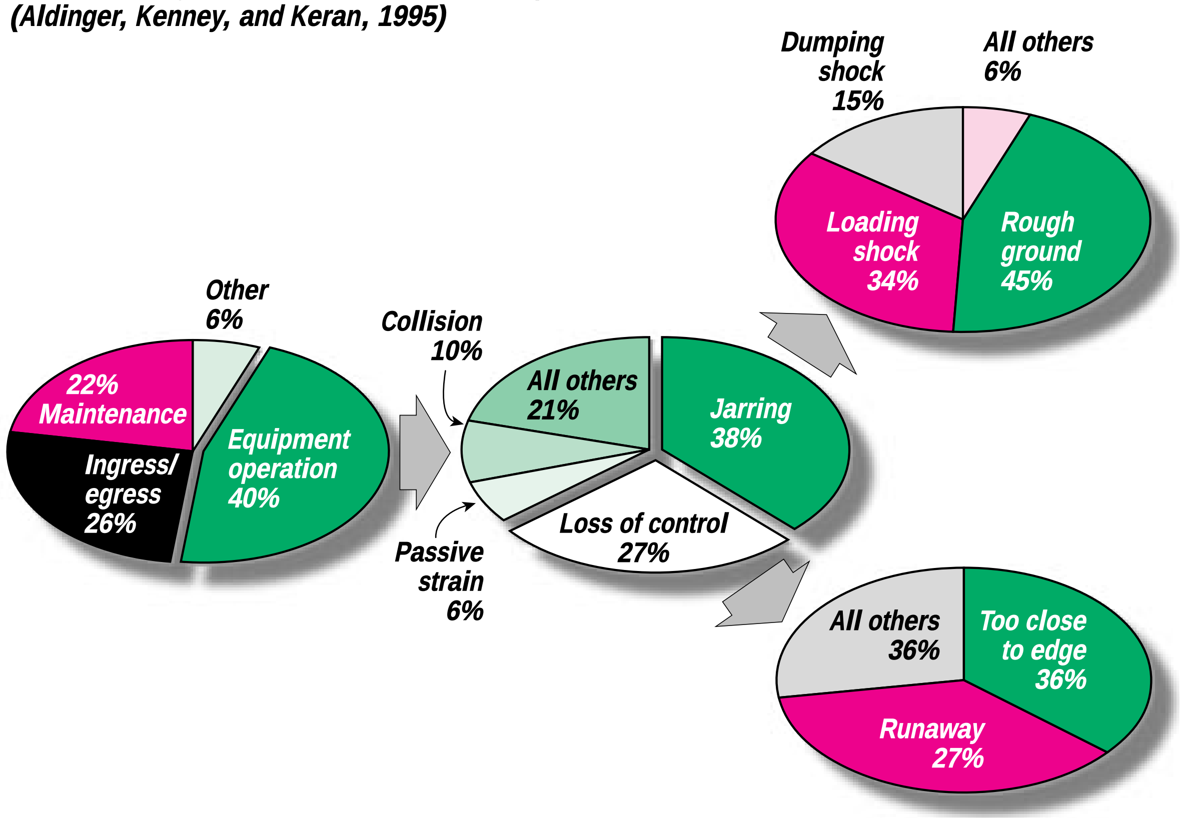
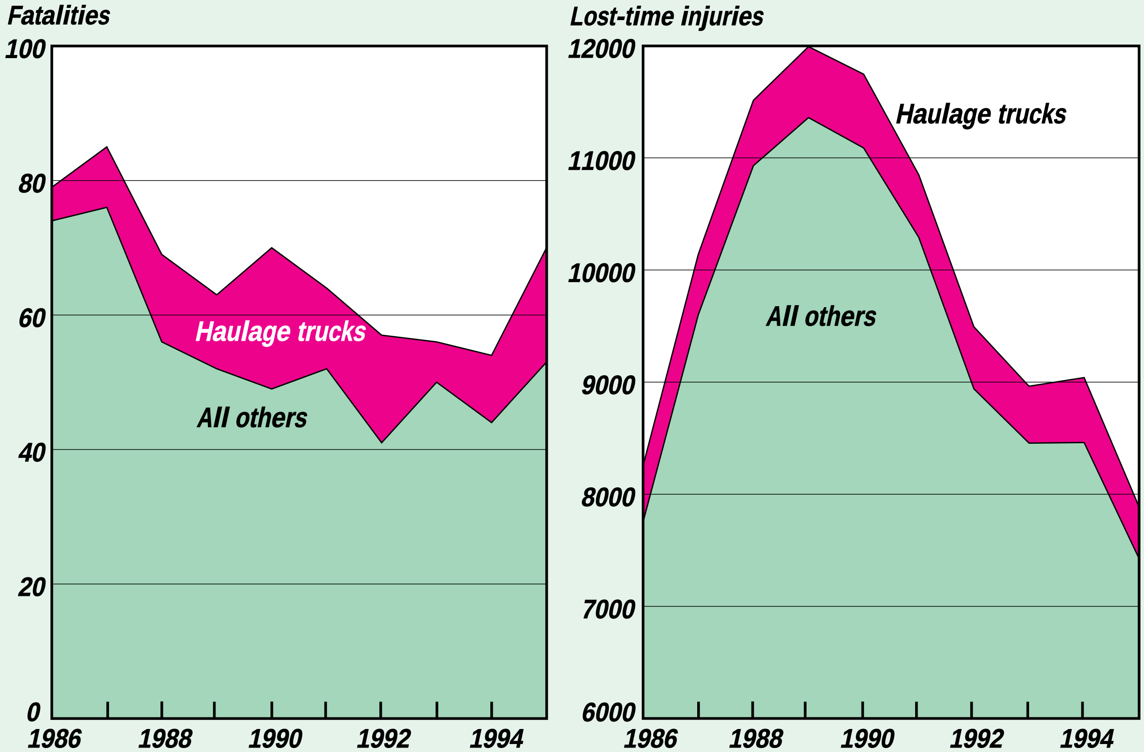


Figure 2.—Surface fatalities and lost-time injuries, 1986–1995.



by Aldinger and Keran (1994) reported whether or not seatbelts were worn, these cases at least suggest some trends. For instance, none of the fatalities in their study involved a victim wearing a seatbelt. Also, injuries tended to be less severe (involving less time off from work) when seatbelts were worn.

Special-purpose data collection

The most expensive, but potentially most rewarding, method of analyzing accident causes is to perform an independent scientific study. Sanders and Shaw (1988) used this method to investigate causal factors in underground mining. They conducted independent investigations of 338 accidents at 20 mines. The investigations resulted in detailed descriptions of each accident, including interviews with employees and a study of the worksite and equipment. The methodology was based on a systems theory of accidents—that is, accidents result from a system of interrelated factors in workplaces, machinery, people, and social structures.

Although this process yielded unprecedented detail about the accidents it studied, it does have some limitations. The 20 mines studied may not be representative of the industry as a whole, especially since the sample consisted mostly of medium-to-large underground coal mines. This type of study also tends to be quite expensive, costing hundreds or thousands of dollars per investigated accident.

Each of these studies has some merits. The strengths of one approach can be used to complement the weaknesses of others and add missing pieces to the overall puzzle of true accident causes.

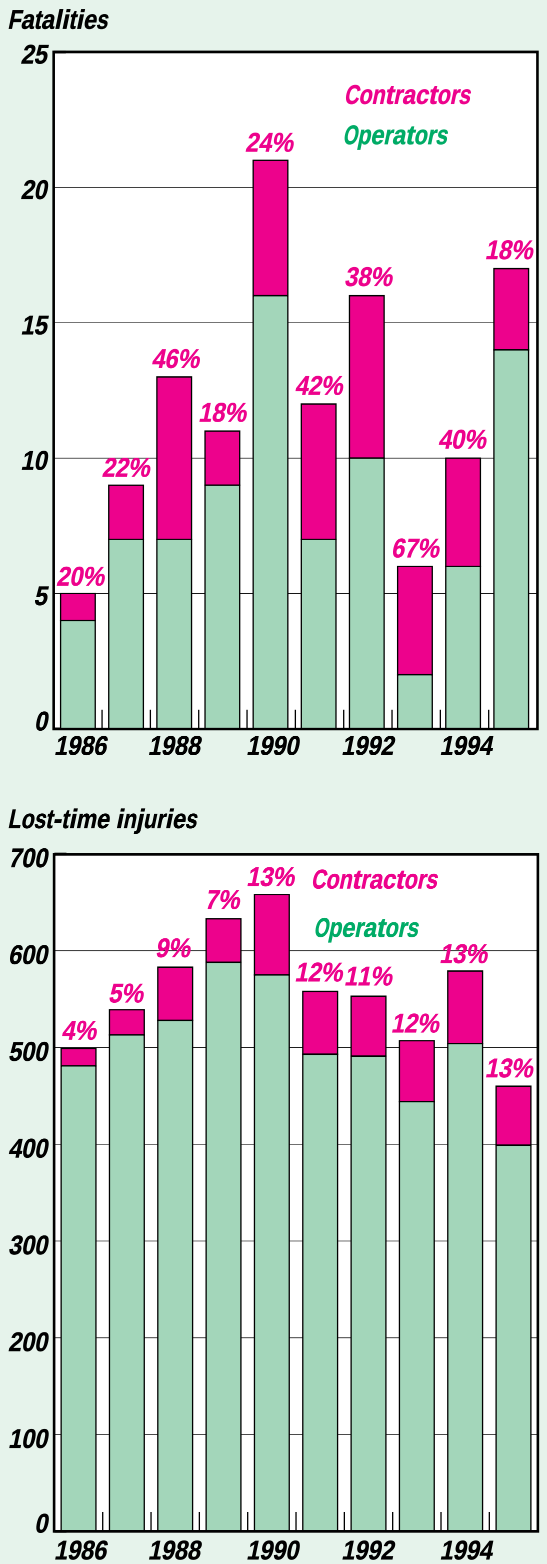
Accident analysis

The accident trends and breakdowns reported here cover accidents in the MSHA database under the category "Ore haulage trucks, off highway and underground." Accidents classified as occurring underground or to office workers were eliminated so that the reported data would reflect surface operations only. The reported data include independent contractors, and, unless otherwise noted, cover the years 1986 through 1995. The 1995 data are currently considered "preliminary" by MSHA.

1986-95 trends

Surface mining fatalities, including haulage truck fatalities, have been generally declining since 1986. However, although the industry attained a historic low of 54 fatalities in 1994, there was a sharp upswing to 70 fatalities in the preliminary 1995 data. A significant component of this upswing was the rise in haulage truck fatalities from 10 to 17. This increase has been a source of concern in the mining community. It would be even more troubling if there were a similar rise in injuries.

Figure 3.—Contractor and operator haulage truck fatalities and lost-time injuries, 1986–1995



Fortunately, lost-time haulage truck injuries declined from 579 in 1994 to 460 in 1995, mirroring an overall surface accident reduction from 9,040 to 7,883 (figure 2). The overall trend since 1989 has been a consistent drop in the number of lost time injuries, with the exception of a slight rise in 1994. The increases prior to 1990 can be attributed to changes and clarifications in reporting practices, rather than to actual increases in accidents (Randolph, 1992; Weaver and Llewellyn, 1986).

Estimated cost

The Accident Cost Indicator Model (ACIM) (DiCanio and Nakata, 1976) was used to estimate the total cost of haulage truck accidents during 1994, the most recent year for which data are available. The ACIM provides cost estimates based on publicly available data on wages, workers' compensation, medical payments, investigation costs, and other direct and indirect costs. Although it has some limitations, including the omission of data on independent contractors, it provides a useful guideline on the magnitude of costs suffered by individuals, industry, and society. According to the ACIM, the six haulage truck fatalities in 1994 cost an estimated \$2.58 million while the 519 lost-time injuries cost \$3.27 million. The total estimated cost for haulage truck fatalities and lost-time injuries in 1994 was more than \$5.8 million.

Independent contractors

The use of independent contractors in the mining workforce is rising. They account for 18% to 67% of the haulage truck fatalities each year (figure 3) and from 4% to 13% of the lost-time injuries. The haulage truck accident fatality rate for contractors has been consistently higher than the rate for mine operator employees, although their lost-time rate has been similar (figure 4). Making conclusions about these accident rate differences is hampered by a lack of information about how many hours are worked by truck drivers. We only know the hours reported by general work location, not by task, job title, equipment operated, or any other more specific characteristics of exposure.

Accident categories

A more detailed picture of haulage truck accidents emerges by looking at the MSHA categories into which they fall (figure 5).

Nature of injury. The "nature of injury" reported for haulage truck fatalities was predominantly "multiple injuries" (64 fatalities) or "crushing" (34) (Figure 5, top left). The nature of lost-time injuries was somewhat different (figure 5, top right). Sprains and strains were the largest category (2,437 injuries), consistent with Aldinger, Kenney, and Keran's reports of jarring as the main accident type.

Body part injured. Haulage truck fatalities tend to be catastrophic, involving serious damage to multiple body parts (figure 5, center left). Lost-time injuries (figure 5, center right) most often involve the back (1,511) or multiple parts (959), which is again consistent with the jarring scenario.

Victim's activity. The most common activity recorded for victims of fatal haulage truck accidents was operating the truck (61) followed by maintenance (12), walking or running (9) and getting on or off the machine (6) (figure 5, bottom left). Operating the truck was also the largest lost-time category (2,447 injuries) followed by "get on or off equipment" (1,489), maintenance (547), and handling supplies or material (331) (figure 5, bottom right). These categories are roughly consistent with the findings of Aldinger, Kenney, and Keran (1995) despite differences in methods and data.

Mine size

Small mines differ from large mines in important ways, including different geology, fewer resources, and the special problems confronted by all small businesses. A common perception in the mining community is that small mines, at least partially because of the factors listed above, are less safe than larger operations. Recent analyses of accident rates at different sizes of underground coal mining operations (Peters and Fotta, 1994) showed that small mines had a higher fatality rate than large mines. However, there was no consistent pattern of higher nonfatal injury rates at smaller mines. Less has been reported about the relationship between mine size and safety at surface mines.

This analysis differs from the preceding breakdowns of surface truck accidents in several key ways. Because it examines the characteristics of mining operations as a possible factor in haulage safety, the analysis had to be restricted to surface mines only, excluding the surface operations of underground mines as well as preparation plants and mills. It also excludes independent contractors because the hours worked by these employees are reported by the contract company and cannot be attributed to any particular size of mining operation. This analysis used data from just a 3-year period to minimize the problems of a constantly changing population of mining operations. The accidents were broken down into five mine-size groupings: 1-10 employees, 11-20, 21-50, 51-100, and over 100. There are very many small surface mining operations—the median mine size is just four employees.

Figure 6 shows the normalized rates (per 200,000 employee-hours) for surface mine fatalities and lost time injuries. The graphs show both the overall rates as well as the rates for haulage trucks alone. The rates are not clearly higher for the smallest mines. The overall fatality rate for 1-10 employee mines (0.0357) was almost the same as that for 51-100 employee mines (0.0349). For

Figure 4.—Contractor and operator haulage truck fatality and lost-time injury rates, 1986–1995

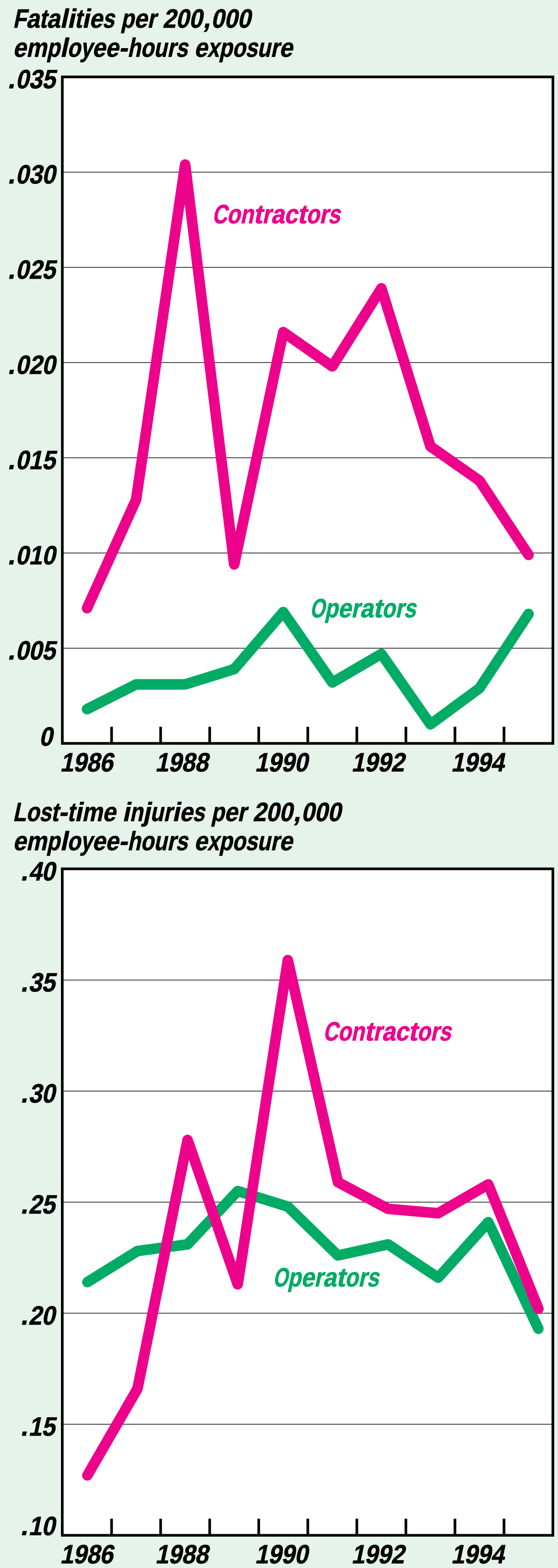


Figure 5.—Haulage truck fatality and lost-time injury categories: Nature of injury, body part injured, and victim's activity, 1986–1995

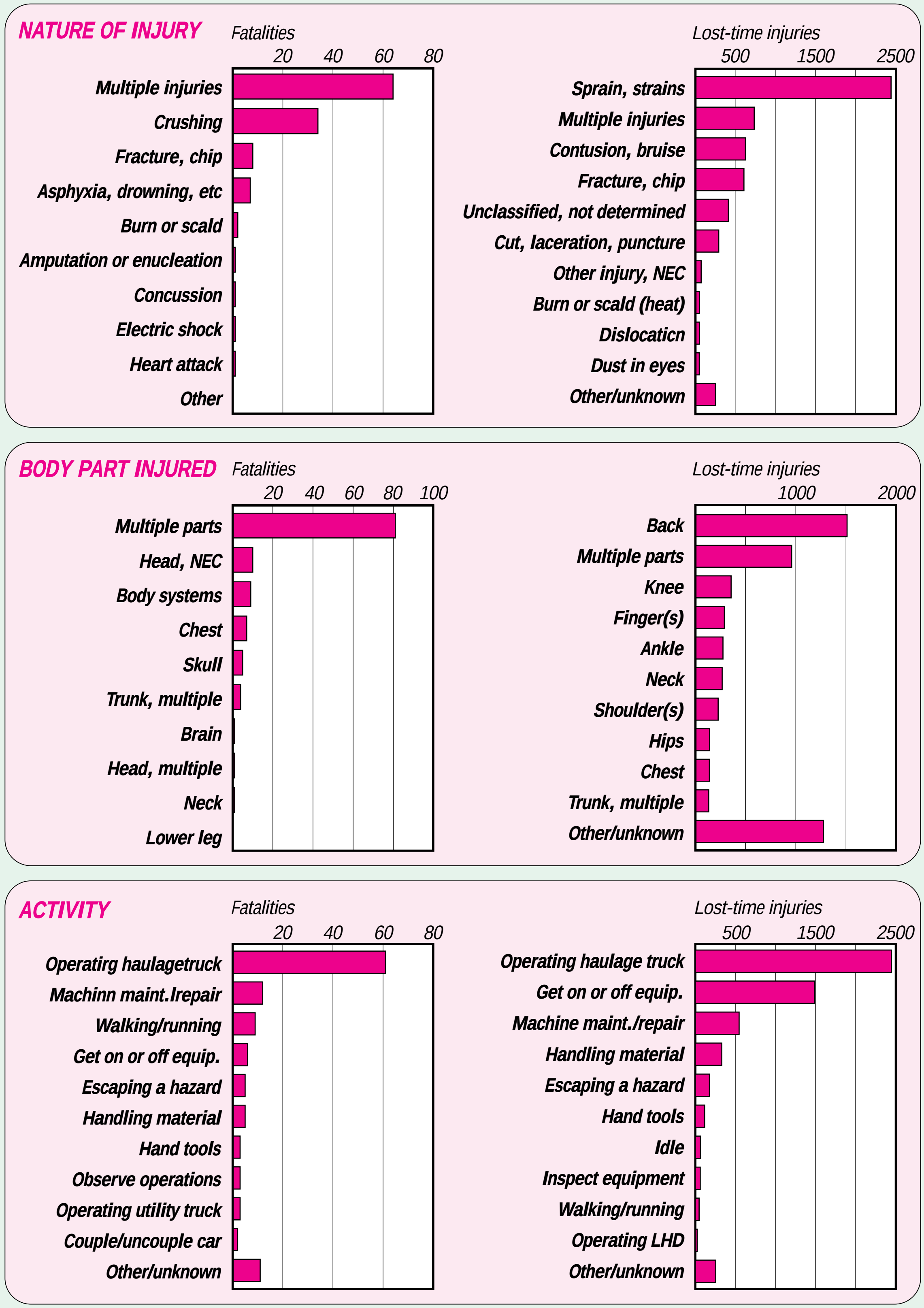
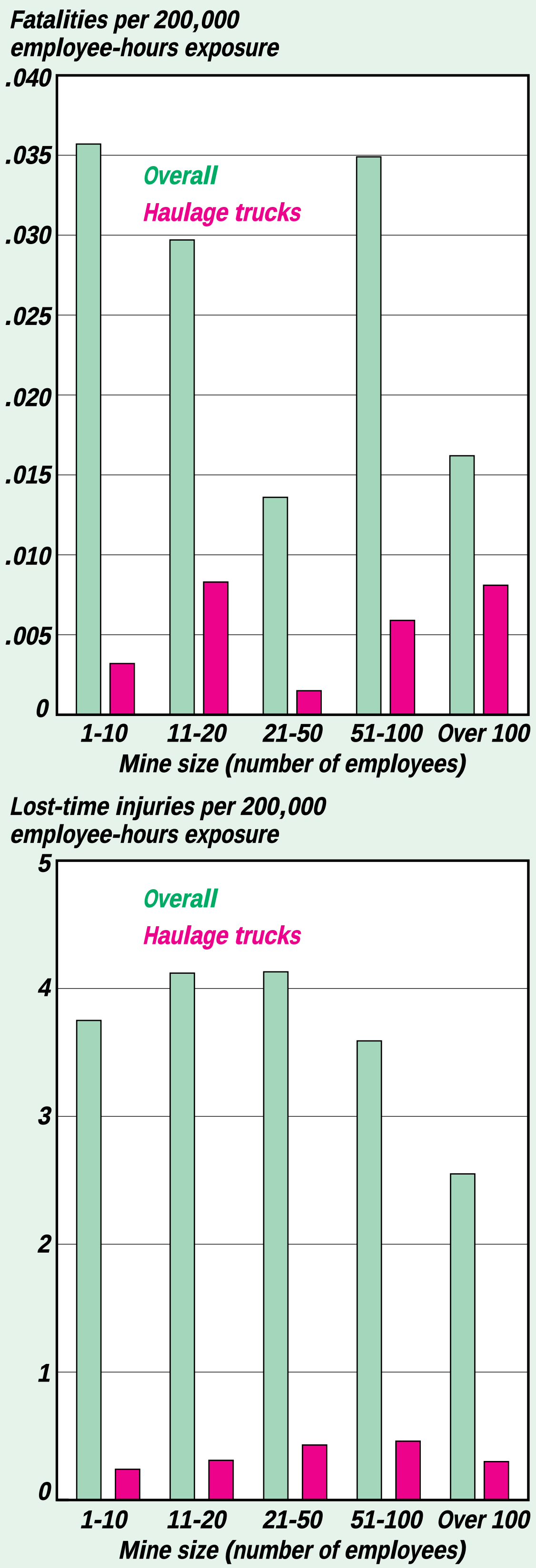


Figure 6.—Fatality and lost-time injury rates for different surface mine sizes, 1986–1995



haulage trucks only, the rate for 11-20 employee mines (0.0083) was the highest by a very small margin over the over-100 employee mines (0.0081). The numbers of fatalities upon which these rates are based were very small, ranging from just one haulage truck death for 21-50 employee mines during 1993-95 to eight fatalities at mines with over 100 employees. Because lost-time injuries occur in much higher numbers, they can be more useful than fatalities for identifying stable overall trends.

The lost-time rates shown in figure 6 reveal that the highest rates are for the middle-sized mines. The 11-20 employee and 21-50 employee mines have the highest overall rates of 4.12 and 4.13, respectively. The peak for haulage truck lost-time injuries is also in the mid-range, but farther along the mine size continuum at 51-100 employees (rate: 0.46). Again, there is no clear trend toward higher rates as mine size decreases.

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Weaver, R. J., and R. G. Llewellyn, 1986 "Report on 30 CFR Part 50" MSHA PC-7014, 49 pp.

Part II of this article will describe the continuing research by the Spokane and Pittsburgh Research centers to address these safety issues.

Underground mine fire preparedness

By William J. Wiehagen, Industrial Engineer, Richard S. Fowkes, Research Physicist, Charles Vaught, Research Sociologist, Ronald S. Conti, Fire Prevention Engineer, and Barbara A. Fotta, Research Methodologist
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Part 1 of 4

This is Part 1 in a series of 4 articles that address underground fire preparedness. The series is primarily based on an analysis of Mine Safety and Health Administration (MSHA) reportable mine fires and information gained from recent interviews with 214 miners at 7 underground coal mines. Answers to the following questions will be addressed based on a data analysis of mine fires occurring from 1978–1992:

• Has the frequency with which underground coal mine fires decreased over the years and, if so, to what extent?
• What have been the most common ignition sources for these fires?
• What have been the most common detection methods for these fires?
• How often have mines been partially or totally evacuated when these fires have occurred?

Answers to the following questions will also be addressed based on interviews with 214 miners at 7 underground coal mines:
• What might be done to help ensure readiness of miners in response to a fire?
• What proportion of the miners interviewed recalled having to evacuate a mine because of a fire?
• What percentage of the miners recalled using a self-rescuer in an emergency?
• What proportion of the miners that were interviewed had experience in helping to extinguish a fire?
• What sorts of training in fighting fires did the miners receive, and what type of training did they want to see emphasized?
• What suggestions did miners make to enhance fire prevention and improve fire-fighting response?

The remaining articles in the series, to be published in subsequent issues, are: Part 2, “Preparedness To Evacuate and Miners’ Experiences With Incipient Fires”; Part 3, “Underground Fire-Fighting Experience and Workers’ Perceptions of Training and Readiness for Fire-Fighting”; and Part 4, “Suggested Improvements and Implications for Training Miners in Fire-Fighting Preparedness.”

It is hoped that the information summarized in this series can elicit discussion and offer some useful information and strategies concerning future investments in the prevention, detection, and response to small underground mine fires. Investments can be made in both people and technology. These investments need to fit both the organizational culture and the work environment. Casual observations suggest that investments in both miners and technology have been quite significant over the years. Most agree that these investments have resulted in greater levels of fire preparedness. Most also agree that zero “fire risk” is just not feasible. What about the future? Perhaps the lessons that we learn from the trends of reportable mine fires, coupled with the experiences of the underground work force, can offer suggestions for future incremental investments in both people and technology to prevent, detect, and respond to underground mine fires.

Study overview and perspective of underground mine fires

Analysis of MSHA reportable mine fires (1978-92)

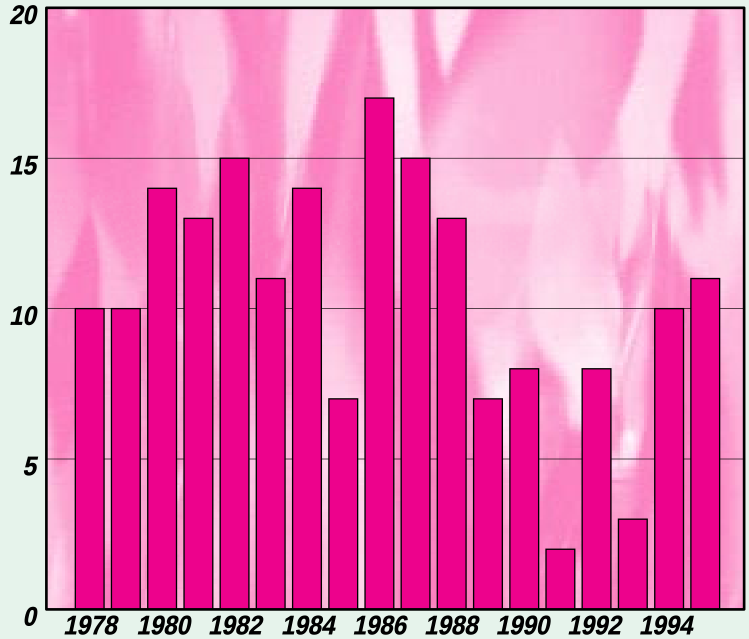
Historically, underground mine fires have been a leading threat to worker safety and to the productive capacity of U.S. coal mines. During the 1950s and 1960s, approximately 50 fires per year were reported to Federal authorities [MacDonald and Pomroy 1980]. Federal regulations require a mine fire to be reported if it results in a fatality or injury or if it is not extinguished within 30 minutes of discovery [30 CFR 1 to 199 (1996)]. Because such incidents were fairly common, a sizable portion of the industry had some experience in dealing with them. Additionally, these people in the industry shared information that allowed them to assess improvements in fire safety over time.

More recently, Pomroy and Carigiet [1995] analyzed 164 underground coal mine fires that occurred between 1978 and 1992 (about 11 fires per year). Figure 1 summarizes this information, augmented with a tabulation of underground mine fires for the last three years (1993-95).

From the MSHA reports (1978-92), Pomroy and Carigiet [1995] tabulated and studied the causes of underground coal mine fires. The information that they found is summarized below.

Underground coal mine fires, 1978–1995

Reportable mine fires



Source: U.S. Mine Safety and Health Administration data

• ***Fatalities and Injuries:*** Over the 15-year period, there were a total of 30 fatalities and 43 injuries resulting from the 164 underground coal mine fires. Of note, 10 of the injuries and 27 of the fatalities are attributed to one event: the Wilberg fire of 1984. The last fatality from an underground coal mine fire occurred in 1987.

• ***Ignition Sources:*** The majority of fires were electrical (such as a short circuit or insulation failure). This was followed by fires due to friction (such as a conveyor belt rubbing on a pulley or stationary object), welding and flame cutting, and spontaneous combustion. The ignition source for 28 of the fires was not reported.

• ***Mining Equipment:*** A variety of mining equipment was involved in the fires. For example, conveyors or conveyor drives accounted for the largest category (33 fires). A variety of face equipment accounted for another 30 fires. This was followed by welding and flame cutting, trolley vehicle or rectifiers, power centers and transformers, and air compressors.

• ***Detection Method:*** The mine fires were detected in a number of ways. By far, the largest category involved fires that were detected by personnel who saw or smelled smoke or witnessed the original ignition (139 fires). Other detection methods included air samples containing gases (seven fires), mine-wide monitoring systems (six fires), electric power lost (four fires), and belt detection system (one fire). The detection method was not reported for seven of the fires.

• ***Mine Evacuation:*** Mine-wide evacuations occurred for 74 of the fires, there were no evacuations for 44, and inby personnel were evacuated for 24. Specific evacuation information was not provided for the other 22 fires.

• ***Method of Extinguishment***: Fire-fighting often involves the use of more than one extinguishing agent. For the 164 reportable mine fires, water remains the most common extinguishing agent. This was followed by dry chemical extinguishers, rock dust, and sealing.

• ***Underground Location:*** Although belt entries accounted for the greatest number of fires, fires on the working section, the intake and track entries, a mined-out gob area, and the shaft or slope bottom also accounted for a sizable number of fires over the 15-year period.

• ***Time:*** There were no dramatic trends (i.e., there was fairly equal distribution) with regard to time (either time of year or time of day).

Several observations can be made based on this analysis of the 164 reportable mine fires:

• ***A variety of mining equipment was involved in the fires***. In most cases, the equipment was the cause of the fire. Over the 15-year period, increasing trends were observed for roof bolters, power centers/transformers/electrical equipment, and conveyor/conveyor drives. Diesel equipment was involved in two of the fires, and reportable fires involving rubber hose/tires and oil/grease are declining. However, the high number of fires associated with conveyors and conveyor drives makes this increasing trend most notable.

• ***Approximately 85% of fires (139 out of 164) were first detected by mining personnel*** who saw smoke, smelled smoke, or saw the fire start.

• ***The entire mine was evacuated for about 45% of the fires and inby personnel for another 15%.*** There appeared to be a strong downward trend in the "no evacuation" category over the 15-year period. Pomroy and Carigiet [1995] note that "the fire report data do not support a definitive explanation for this increase in the percentage of fires resulting in total or partial evacuation. It may result from a generally increased level of knowledge of, and caution by, management regarding the risks to underground personnel from fire."

• ***None of the extinguishing methods were successful in all cases***. Many fires required, as expected, a combination of extinguishing agents. Water is still the most often used fire suppression agent for fires beyond the incipient stage.

• ***There were seven general locations for the fires.*** This implies that fire initiation is a mine-wide problem.

• ***There is little difference between the number of fires discovered and reported for the three different shifts, nor much difference evidenced for the time of year.***

• ***Both the fire and injury incidence rate declined dramatically*** when comparing reportable mine fires occurring over the baseline period (1950-77) with the current study period (1978-92). The likely causes of this decrease are safer mining equipment and practices, and stricter enforcement of mine fire safety regulations.

• ***A mine fire can occur at any time in any place in the mine.*** The likely result, two-thirds of the time, is partial or total evacuation of mining personnel.

The most recent data obtained from abstracts (incidents classified as underground mine fires) prepared by MSHA for 1993 through 1995 showed the following:

• There were 3 underground coal mine fires in 1993, 10 in 1994, and 11 in 1995, for a total of 24 in the

3-year period. ***The average was 8 fires per year, a somewhat lower average than the 11 fires per year for 1978 through 1992.***

• ***There were no fatalities due to underground coal mine fires during 1993-95.***

• ***The ignition source was electrical in about 50% of the fires.*** This was followed by welding and cutting, friction, and spontaneous combustion.

• In those cases where the equipment involved is specified, a shuttle car was involved in one fire, a ram car in two, a scoop in three, and a jeep in one.

• The MSHA abstracts revealed that one fire occurred in a sealed area, five at the face, one in an elevator shaft, and six outby (two on a belt line and one in a mechanic's storage area).

The above data reinforce a perception voiced at MSHA's Mine Emergency Preparedness Conference: ***Mine fires now verge upon the nonroutine*** [Mine Emergency Preparedness Conference 1995]. This presents several interesting points. First, people who are relatively newly employed in underground mining may never have had to respond to a hazardous event. Such a situation tends to foster complacence. Secondly, 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 data base has been eroded to the point that reportable fires will be less reliable as a dependent measure of effect. One implication of this trend is that the future adoption of any new technology, for instance, might not show a large reduction in the absolute number of mine fires reported each year because so few are occurring. Reaching this important plateau in underground fire safety also brings an opportunity to seek other and better means to cultivate economically prudent improvements in reducing fire risk. In other words, we are all faced with an interesting paradox: fewer and fewer "reportable" mine fires are good testimony to past and ongoing efforts in fire prevention, detection, and response. However, reaching this plateau offers little insight to the future in seeking more cost-effective ways to achieve the next, but not as yet defined, plateau. The problem is that without a goal or destination, any path might get us where we think we are going. As the articles in this series portray, risk reduction is only measured through hindsight. Or can we perhaps learn from the past, integrate the present, and select a reasonable direction? This might be prudent, as many in the mining industry fully appreciate that small fires still occur. In fact, fires can be thought of as a constant. In other words, one known risk of being in the mining business is the risk of catastrophic loss, such as that occurring due to fires. There is enormous potential for social and economic costs accruing to any one of these fires that, in their incipient stage might be benign, but in reality can be of significant consequence.

That potential became a reality at some operations over the past 15 years. The 1984 Wilberg disaster, for instance, claimed 27 lives. The permanent sealing of BethEnergy's Marianna Mine in 1988 and National Mines' Mathies operation in 1990 cost over 1,000 jobs. Conti [1994] indicated that the cost of this mine fire was estimated at $23 million. Included are the losses of mining equipment and supplies and the expense of sealing the mine. 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. There is evidence that capability can be equated with a readiness to act rapidly and effectively. It is certain that a quick response depends on both people and technology.

Elapsed time between the onset of a mine fire and its detection is critical because fires tend to grow quickly in size and intensity [Mitchell 1990]. 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 actually 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. Because the first couple of hours are crucial, according to Mitchell [1990], efforts of ordinary workers and front-line supervisors may actually have the best chance of preventing a mine from being sealed due to a fire. Although their role is pivotal, not much *is known about how well the underground mining force might be able to perform in the event of a fire.* 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. As Conti [1994] has noted, "the success of safely controlling an incipient fire depends on several factors, such as an awareness of the fire hazards, early detection, availability of effective fire-fighting equipment, quick response time, and trained firefighters." A few of the resources and facilities available to help increase the mining industry's awareness of technology and human resource strategies to help prevent, detect, and respond to underground mine fires include (1) MSHA's National Mine Health and Safety Academy, Beckley, WV, (2) NIOSH (formerly the U.S. Bureau of Mines) Open Industry Briefings at Lake Lynn Laboratory near Fairchance, Fayette County, PA, and (3) the West Virginia Mining Extension Service.

Interviews with underground coal miners

Without question, official, recorded accounts of mine fires and related injuries are the most important measure of industry-wide progress in mine fire preparedness. However, many incipient fires are not officially reported because the fires are extinguished quickly and without injury. Although not addressed in the study by Pomroy and Carigiet [1995], another factor that perhaps has significant bearing on the industry-wide success in reducing fire loss is the growing levels of experience of today's underground work force. To obtain a better understanding of fire preparedness from the experience levels of these workers, we interviewed 214 miners from 7 underground coal mines [Vaught et al. 1996]. The purpose was to determine their state of preparedness and the technology they use to detect and respond to underground mine fires. All interviews were voluntary and were conducted one-on-one. In most cases, they were conducted underground, at the miners' normal work location. A few were conducted at surface facilities of the underground mine either just before or at the conclusion of a working shift. The interviews lasted approximately 20 to 60 minutes depending on the length of each miner's responses to open-ended questions. Accounts were gathered during both the daylight and afternoon shifts. All but a few of the 214 miners interviewed agreed to have their account recorded. This allowed for accuracy in the collection and interpretation of the data.

Because of the nature of the questions, the summary data did not, in all cases, distinguish the fire experiences of miners while employed at the particular mine site from previous experiences working at other sites.

A description of each of the mine sites is summarized in Report of Investigations (RI) 9584 [Vaught 1996]. The selection of the seven mines included in the study was based on the researchers' contacts with mine management. These operations varied by geographic location and mine size (based on the number of employees). All operations were mining coal seams > 48 inches.

Are these seven mines typical of other mines in the industry? With a small sample size, one can only extrapolate based on the characteristics of the sample. Consider for example:

- Four mines used longwalls as the predominant method of production; the annual production of all seven mines ranged from 226,000 to 5 million tons; four mines were represented by a labor union; three mines were in the East, two mines in the Midwest, and two mines in the West; one mine was a small mine employing 40 miners, the remaining mines employed 225 to 500 miners.
- With regard to MSHA reportable mine fires, only one of the mines had a reportable mine fire over a 5-year period prior to this study.
- The study sample tended to underrepresent the characteristics of the general U.S. underground coal industry with regard to small mines (i.e., those employing fewer than 50 miners) and seam height. Only one of the 7 mines employed fewer than 50 miners (mine A), and low-seam mines were not part of the original study. This might be an area for further study, as one could argue that lower-seam heights introduce some unique problems in fire prevention and response.

The fact that only one of these seven mines had an MSHA reportable mine fire suggests that reportable mine fires might tell us something about the past, but might not necessarily be a good indicator of fire preparedness (or fire risk) in the present. If we accept this and couple this notion with the wide variability in the response of miners concerning their experiences in fire response and evacuation, then it might offer a new way to think about fire preparedness. This notion is central to the work reported in this series of articles. In fact, we assert that it might be helpful for mine safety personnel and mining organizations to consider that ***small mine fires will always occur.*** Why? Because it offers an opportunity for individual mine sites to gather meaningful and proactive data about the risk of small fires and the anticipated preparedness of the work force to respond to these incidents. Small fire incidents at the work site can be used in an instructional sense and to explore enhancements in fire prevention and response technology.

The mine descriptions are intentionally nonspecific to maintain the anonymity of the seven participating sites. They will be referred to in this series of articles as mines A through G.

The average miner in this sample was 39 years old and possessed more than 14 years of mining experience. Therefore, much of the self-reported data (e.g., evacuation and fire response incidents) gathered during these interviews draws completely from the collective 3,000+ years of mining experience captured through this study.

The interviews provided information that can be organized into several topics: (1) preparedness to evacuate, (2) experience with incipient fires, (3) underground fire-fighting experience, (4) workers' perceptions of training and readiness for fire-fighting, (5) miners' perceptions of their units as fire-fight units, and (6) suggested improvements in fire-fighting preparedness.

To highlight some of the findings across all seven mines:

• The proportion of respondents who had to evacuate due to 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 at mines F and G. "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."

• For all of the mines, approximately 21% indicated that they had donned either a filter self-rescuer or a self-contained self-rescuer in an emergency. The actual percentages that had donned apparatus ranged from 11% at mine A to 31% at mine F.

• Many individuals were involved in one or more fire-fighting incidents. Across the seven mines, approximately 70% had indicated some direct experience in helping extinguish a fire. "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."

• Many miners reported that their training consisted of a combination of either lectures (being told what to do) or discussion (talking about it). Workers at mines B, C, D, and F described their training as consisting primarily of lectures and discussion. Conversely, more miners at mines A and E described their training as entailing a hands-on approach. At mine G, this approach was often in combination with lectures and/or discussion.

• At four of the mines (C, D, E and F), about 70% of the workers believed that they possessed 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 at mine B believed that 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 involving a hands-on approach.

Although other examples and details will be presented later in this series of articles, the picture that emerges from these interviews, by and large, is one of variability. Significantly greater percentages of interviewees had walked their escapeways at some operations than at others. The same is true for those who recently participated in fire drills. The broad types of training offered to the work force also varied. Some mines relied heavily on 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 two mines was at least once per week, whereas at another mine it was about once per year. In many instances, miners may well be aware of what's causing the smoke. However, this might be problematic if the source of the smoke is different than their expectation. The most consistent part of this picture is captured by the finding that, across all seven mines, about *70% of those interviewed had, at some time during their career, fought a fire underground.* This suggests that fire is a constant. To help ensure adequate readiness in the response to fire, several recommendations resulted from this study:

• Pay attention to the selection and placement of fire detection sensors.

• Establish and test warning and communication protocols in the event of an emergency.

• Develop and test a water delivery system capable of delivering hundreds of gallons of water per minute for sustained periods.

• Conduct formal fire preparedness audits.

• Develop case studies of fire incidents that can be used as teaching and assessment tools.

• Provide opportunities for structured practice that can be incorporated into fire drills.

Part II in the next issue will address some of the specific data from the interviews and perceptions of miners in their preparedness to evacuate and their experiences with incipient fires.

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Rise in mine deaths concerns federal officials

A steep rise in metal and nonmetal mining deaths this year has Federal mine safety officials looking hard at mine safety concerns outside the coal industry. From January 1 through April 20, 1997, 22 employees in the mining industry's non-coal sector died in accidents, compared with 10 in the same period last year, the Mine Safety and Health Administration (MSHA) reported.

"We in MSHA are not sure what's caused the increase, but we are seeing some indications of patterns in the accidents," said Davitt McAteer, Assistant Secretary of Labor for Mine Safety and Health. "We've asked leaders of industry and labor organizations in the metal and nonmetal mining industry to meet with us and critically examine what it will take to turn this around."

Concentrations of metal and nonmetal mining deaths have occurred in several mining regions during recent years. From January 1994 through April 20, 1997, 18 Nevada miners lost their lives in accidents, 3 of them in 1997. California saw 16 miner deaths in the same period, including 4 this year. Missouri has had 10 metal and nonmetal mining fatalities from 1994 through April 20, 1997, including 2 this year.

Smaller concentrations of metal and nonmetal mining fatalities from 1994 through April 20, 1997 occurred in Pennsylvania (8), Arizona (7), Florida (6), Georgia (6), Texas (6), Virginia(5), and Washington (5).

MSHA has temporarily assigned 10 metal and nonmetal mine inspectors from other areas of the country to areas of special concern. Eight of the 10 were assigned to the agency's Western District, covering Nevada and California, where a number of recent fatalities were concentrated.

In addition, MSHA has moved to deploy training personnel, engineers and other specialists who will conduct special safety meetings, technical surveys and other activities focused on accident prevention in metal and nonmetal mines, especially where deaths have concentrated.

"Specialists will focus their efforts on areas of current safety concern. In addition, MSHA's metal and nonmetal mine inspectors will highlight the recent fatalities with mine operators and miners during their regular inspections," McAteer said.

"Many of the recent fatalities in this industry have occurred during operation of vehicles and other mobile equipment," McAteer said. "Maintenance, repair and construction all are hazardous activities for metal and nonmetal miners. In addition, we are concerned about the number of fatalities due to ground collapses. Our specialists will emphasize these safety issues."

McAteer noted that crushed stone, sand and gravel, and gold and silver operations have experienced a disturbing number of fatal accidents. Crushed stone operations have accounted for 67 miner deaths since 1994; sand and gravel operations experienced 30, and gold and silver operations had 26 deaths since 1994.

In addition, independent contractors working at mine sites have accounted for a disproportionate number of mine fatalities. Safety at cement operations is another concern, with two dual-fatality accidents at cement kilns last year.

"We are asking mining industry and labor groups to work with us in addressing these concerns," McAteer said.

1997 Fatal accidents at metal and nonmetal mines

January 1–April 17, 1997

Preliminary data

Case	State	Date	Type of operation	Type of accident
1.	Wash.	1/8	Sand and gravel	Machinery
2.	Nev.	1/14	Gold	Haulage (conveyor)
3.	Nev.	1/15	Gold	Haulage (loader)
4.	Fla.	1/17	Cement	Fall of person
5.	Tenn.	2/3	Zinc	Fall of roof
6.	Nev.	2/5	Gold	Fall of roof
7.	Calif.	2/3	Sand and gravel	Haulage (conveyor)
8.	Ore.	2/3	Stone	Haulage (truck)
9.	Texas	2/14	Stone	Haulage (loader)
10.	Mo.	2/15	Stone	Fall of highwall
11.	Kans.	2/17	Sand and gravel	Haulage (truck)
12.	S.C.	2/20	Gold	Haulage (truck)
13.	Kans.	2/24	Sand and gravel	Haulage (truck)
14.	Calif.	2/26	Iron	Fall of highwall
15.	Fla.	3/6	Stone	Exploding vessel
16.	Calif.	3/13	Gold	Haulage (truck)
17.	Calif.	3/15	Sand and gravel	Machinery
18.	Texas	3/24	Sand and gravel	Haulage (conveyor)
19.	Tenn.	4/1	Stone	Fall of roof
20.	Mo.	4/9	Stone	Haulage (conveyor)
21.	Ariz.	4/10	Copper	Electricity
22.	Alaska	4/13	Gold	Machinery

In addition, McAteer urged miners and mine operators to educate themselves about recent fatal accidents. MSHA accident investigation reports on mine fatalities are available on the agency's World Wide Web site at www.msha.gov in the section on accident, injury, illness, employment and coal production information. MSHA also posts preliminary information about fatal accidents under investigation.

"We need to learn from each accident to prevent the next," McAteer said.

The U.S. metal and nonmetal (non-coal) mining industry includes about 230,000 employees at underground and surface operations producing metals, nonmetallic minerals, stone, cement, sand and gravel.

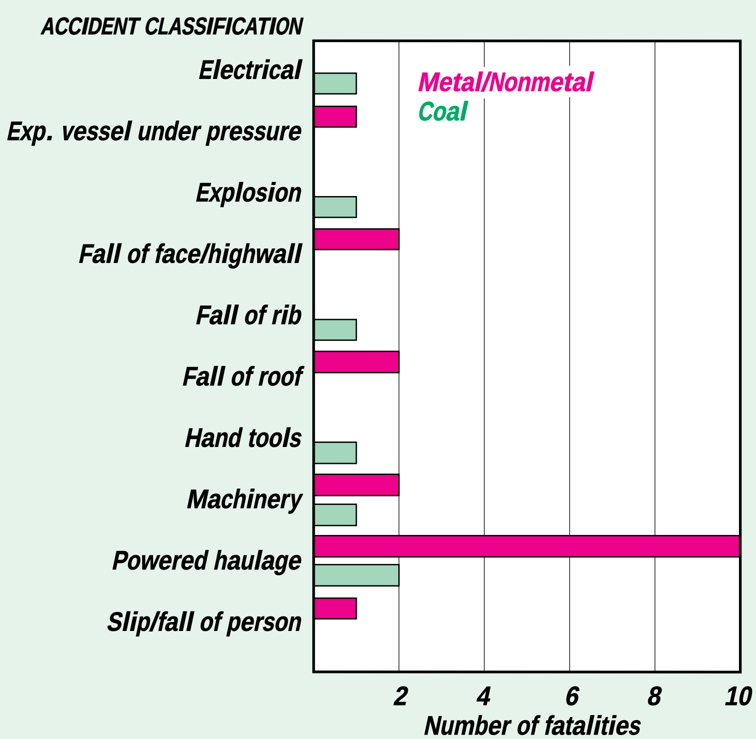
In the coal industry, fatalities stood at 8 this year as of April 17, compared with 14 at the same time in 1996.

Source:
MSHA News Release No. 97-0403
Mine Safety and Health Administration
For Release: 9:00 a.m. EST
Contact: Kathrine Snyder

Summary of first quarter mining data*

This article updates the status of fatalities occurring in both coal and metal/nonmetal mines from January through March of 1997. Based on preliminary accident reports, as of March 31, 1997, twenty-five fatalities have occurred at coal and metal/nonmetal mining operations. During this period, seven fatalities occurred at coal operations and eighteen fatalities occurred at metal/nonmetal operations. Powered haulage fatalities, in both coal and metal/nonmetal were the most frequent accident classification, causing 48 percent of the fatal injuries. Machinery accidents accounted for 12 percent of the fatalities and roof falls and fall of face/highwall each accounted for 8 percent of the fatalities.

FATALITY SUMMARY, JANUARY-MARCH 1997
Based on preliminary accident reports as of 3/31/97



Below is a summary of coal and metal/nonmetal statistics:

Coal Mining

Two of the fatalities were classified as powered haulage. Of the seven fatalities, three occurred in West Virginia, two in Pennsylvania, and one each occurred in Kentucky and Illinois. Six fatalities occurred underground and one occurred on the surface.

Metal/Nonmetal Mining

Ten of the fatalities were classified as powered haulage and 2 each were fall of face/highwall, fall of roof, and machinery. Six fatalities occurred at sand and gravel operations, 5 occurred at gold operations and two each occurred at stone and limestone operations. Four fatalities occurred in California, three occurred in Nevada, and two each occurred in Florida, Kansas and Texas. Fifteen of the fatalities occurred at surface operations, the remaining three fatalities occurred at underground facilities.

** Preliminary statistics.*

MSHA announces the release of a new video: "Dust Control—It's Everyone's Business"