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Committee on Underground Coal Mine Safety
Commission on Engineering and Technical Systems
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Brief biographies of the committee members appear in Appendix B to this report.

PREFACE

This report is the result of a study investigating the safety of underground coal mines in the United States. Its purpose is to persuade and to help those in authority to reduce the number of accidents that injure and kill workers in the nation's underground coal mines. The study was recommended by the President's Commission on Coal, chaired by Governor John D. Rockefeller IV of West Virginia, which urged

> . . . that a thorough investigation of the factors that distinguish the safest from the most dangerous mines be undertaken immediately by the National Academy of Sciences, cooperating with labor, management, and MSHA; that this investigation start from the Commission's findings that unacceptably wide variation exists in the safety experience among larger underground mines and that fatalities are disproportionately high in smaller underground mines; and that specific recommendations be made to management, labor, and MSHA for the exercise of continued joint responsibility for improving underground mine safety.

The study was sponsored by the U.S. Bureau of Mines, Department of the Interior, through Contract No. J0100145 with the National Academy of Sciences.

In order to perform the study a Committee on Underground Coal Mine Safety was appointed by the chairman of the Commission on Sociotechnical Systems of the National Research Council, the operating arm of the Academy. A conscious effort was made to form an interdisciplinary committee--one that would reflect both the technologies and the social sciences applicable to coal mining. The technologies represented on the Committee include mining engineering, geology, industrial safety, industrial management, and medicine. Committee members representing the social sciences include a sociologist, a psychologist, an economist, a lawyer, and a labor leader. Finally, we needed a statistician to analyze the voluminous data on miner injuries and fatalities, which were a valuable resource in conducting this study.

After several months of deliberations and discussions with experts on coal mining and mine safety, the Committee directed its attention to two major questions:

1. Why are some underground coal mines in the United States safer than others?
2. What can be done to make U.S. underground coal mines safer than they are today?

This report is an attempt to answer these two questions and, in doing so, to address corollary and supplementary issues that are pertinent to underground coal mine safety. Our answers to the two principal questions appear in Chapter 1, "Findings," and in Chapter 2, "Options for Action." Chapter 3 makes available to the reader some background information about coal mining that may help in understanding the report. Chapter 4 gives the results of statistical analyses undertaken by the Committee to support the study. Chapter 5 reports on our visits to 12 underground coal mines in widely different parts of the United States.

This study pertains to injuries, including fatalities, that are the result of accidents in underground coal mines; it does not deal with health problems arising from the mine environment--another and a different problem.

During the course of the study we received generous assistance from organizations and representatives of the industry, from labor, and from government. I take this opportunity to express my gratitude to everyone who helped us and to those who may, inadvertently, have been omitted from the acknowledgments. Finally, I wish to express my deepest appreciation to the members of the Committee on Underground Coal Mine Safety for their devotion to the task set before us, for their well-conceived contributions to this report, and for their steadfast support of the chairman.

Ernest M. Spokes

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Julius Piore, Director of Safety

CONTENTS

INTRODUCTION AND OVERVIEW

The safety of workers in the underground coal mines of the United States depends on a complex mixture of many technical and social factors. There is danger in being underground: The passages are uneven, sometimes wet, and not well illuminated. Roof falls account for about half of all fatalities. Methane and coal dust, if not properly controlled, can be ignited to produce an explosive shock wave, creating a nightmare of death and destruction. Most underground coal mines use large machinery--continuous miners, shuttle cars, mantrips, and conveyors--to mine and transport the coal (and also the miners), and much of this is powered by electricity. Miners always must be alert not to be crushed against the walls and low ceilings of narrow passageways or to be electrocuted by touching exposed circuits and trolley wires. In a factory the same workplace is used day after day, and its safety can be studied and improved. In a mine the workplace changes daily; miners must live constantly with the unexpected.

The careful, well-trained miner learns to cope with these hazards and avoid injury. But miners become weary and careless: Some develop a fatalistic attitude toward their own safety. Some miners take risks and short cuts because they think the company expects them to do so and because they see their risk taking tolerated by a management that puts production first and safety second. But in other mines risk taking is not tolerated; miners who do so are disciplined, as are foremen who permit such practices. In such mines, workers and supervisors are trained in safe work habits, and they cooperate in a continual effort to make their mines even safer. The results are evident: Some mines have substantially lower injury and fatality rates than others. Why? Why are some underground coal mines safer than others?

To be sure, the mines are safer today than they were 10, 20, or 50 years ago. In the 1930s and 1940s more than 1,000 miners were killed yearly in underground coal mines; today the number is about 100 annually. There are fewer miners today, so the decrease in fatality rate amounts to only a factor of four. But this is still very significant. Disabling injury rates have not decreased as much, but the causes of these injuries have changed. Slips or falls of persons, striking or bumping an object, and lifting, pulling, pushing, and shoveling are the causes that now predominate. As a result, on the average, injuries are less severe that they used to be.

What has brought about this improvement in safety? Some of it is due to better laws and stricter enforcement, especially by the federal government. Some of it is due to better knowledge of the geological conditions in underground coal mines. Some of it is due to better technology: continuous miners with canopies, roof bolters with temporary roof supports, and better ventilation. But these factors operate in mines that have high injury rates as well as in those that have low injury rates. We must look elsewhere to understand the differences.

Our Committee began its investigation by seeking the advice of many experts on coal mining: officials of the Mine Safety and Health Administration (MSHA) and of the U.S. Bureau of Mines, executives of coal companies, union officials, coal miners, and directors of research agencies. It was their unanimous opinion that the keys to further improvement in mine safety could not be found in the existing literature on the subject or in the application of existing rules of good practice; the industry already knows and accepts such knowledge. Rather, the keys to the present situation are the people involved in mining coal, their attitudes and motivations. Therefore the Committee undertook its own investigations. It obtained data on every disabling injury that was reported to have occurred in a U.S. underground coal mine during the three-year period 1978-80; such injuries numbered nearly 40,000, including fatalities. These data were analyzed for correlations between injury rates by mine and company and such factors as type of accident, mine size, seam thickness, union status, productivity, geographical location (by state), and age of miners.

We found that there are large and persistent differences between the injury rates of the major companies that control underground coal mines in the United States.

Such differences could not be explained by physical, technological, or geographical factors that we analyzed; they are due, rather, to factors internal to the companies. From our visits to underground coal mines, our case studies of coal companies, and our discussions with industry, union, and government officials, we found the most important of these factors to be (1) management's commitment, as reflected by the attention and resources it devotes to improving safety, (2) cooperation between management and labor in developing and implementing safety programs, and (3) the quality of training of employees and managers. These findings are discussed in Chapters 1 and 4 of this report.

We found further from our analyses that there is a strong correlation between disabling injuries and the age of miners--younger miners have a higher injury rate. We also found a strong correlation between mine size and fatal injuries--smaller mines have a higher fatality rate.

What can be done to improve this situation and make underground coal mines safer than they are today? Our finding is stated in Chapter 1. The primary initiative for achieving and maintaining improved coal mine safety must come from the managements of coal companies. They alone have the authority within their companies to establish policies and priorities and communicate them throughout their organizations. They alone have the authority to implement safety programs, commit resources, and reward their managers and employees for achieving the goals of those programs. The goals may not be attainable without the cooperation of employees, but only management has the authority to request of its employees the actions needed to realize those goals.

The options available to management (and to labor) are set forth in Chapter 2 of this report. Foremost among these options are (1) a greater commitment to safety on the part of mine company managements, (2) a higher degree of cooperation between management and labor in the implementation of safety, and (3) better education of employees and managers in the techniques of safety.

The federal and state governments can both help; the options available to them are also set forth in Chapter 2. They include (1) continued enforcement of laws governing safety by federal and state governments, (2) an augmentation by MSHA of the advisory services available to the industry, and (3) a substantial increase in the support of mining education (at universities and technical schools) by state governments.

In Table 24 of this report (see Chapter 4) we list 19 major coal companies according to their disabling injury rates (R_D) for the years 1978-80.* The nine companies at the top of the list had an average R_D of 8. The ten companies at the bottom of the list had an average R_D of 16.7, over twice as great. The latter companies had 12,927 disabling injuries to underground miners during the three-year period. If these ten companies could have had an injury rate equal to that of the top nine companies, 6,734 of their injuries would not have occurred. This example from the past illustrates what might be achieved in the future. We are convinced it is feasible.

*R_D is the average number of injuries per 200,000 employee-hours (the number of hours worked by 100 full-time miners in a year).

1

FINDINGS

In answer to the question "Why are some underground coal mines in the United States safer than others?" we concluded:

I. THERE ARE PERSISTENT AND LARGE DIFFERENCES BETWEEN THE INJURY RATES OF COMPANIES THAT CONTROL UNDERGROUND COAL MINES. THESE DIFFERENCES COULD NOT BE EXPLAINED BY PHYSICAL, TECHNOLOGICAL, OR GEOGRAPHICAL CONDITIONS, BUT ARE DUE TO FACTORS INTERNAL TO THE COMPANIES. IN OUR OPINION, THE MOST IMPORTANT OF THESE FACTORS ARE:

A. MANAGEMENT'S COMMITMENT, AS REFLECTED BY THE ATTENTION AND RESOURCES IT DEVOTES TO IMPROVING SAFETY.
B. COOPERATION BETWEEN MANAGEMENT AND LABOR IN DEVELOPING AND IMPLEMENTING SAFETY PROGRAMS.
C. THE QUALITY OF TRAINING OF EMPLOYEES AND MANAGERS OF COAL MINING COMPANIES.

II. THERE IS A STRONG CORRELATION BETWEEN AGE AND DISABLING INJURIES. THE DISABLING INJURY RATE FOR MINERS 18-24 YEARS OF AGE IS ABOUT THREE TIMES THAT OF MINERS OVER 45, AND ABOUT TWICE THAT OF MINERS BETWEEN 25 AND 45.

III. THERE IS A STRONG CORRELATION BETWEEN MINE SIZE AND FATAL INJURIES. THE FATALITY RATE IN MINES WITH 50 OR FEWER EMPLOYEES IS NEARLY THREE TIMES THAT OF LARGE MINES (WITH OVER 250 EMPLOYEES), AND ABOUT TWICE THAT OF INTERMEDIATE-SIZED MINES (WITH 51-250 EMPLOYEES).

Below we discuss these three conclusions in order.

I. THERE ARE LARGE DIFFERENCES IN THE DISABLING INJURY RATES OF COMPANIES THAT CONTROL UNDERGROUND COAL MINES

Of the 19 companies (the 19 largest in the United States) that we analyzed in detail (see Table 24, Chapter 4), the three safest companies have an average disabling injury rate of 5; the three least safe have an average disabling injury rate of 20. In other words, a miner is four times as likely to be injured in mines of the latter three companies than in mines of the former three companies. A full discussion of how these injury rates were derived is given in Chapter 4. For purposes of this chapter, it is sufficient to note that such large differences in injury rate exist and proceed to a discussion of the factors to which we attribute them.

A. Management's Commitment

State and federal legislation has contributed to improved safety in underground coal mines over the past several decades, but a company's compliance with prescribed safety standards will not *by itself* produce an outstanding safety record. The initiative to achieve and maintain excellent safety must come from the managements of coal companies. They alone have the authority within their companies to establish policies and priorities and communicate them throughout their organizations. They alone have the authority to implement safety programs, commit resources, and reward their managers and employees for achieving the goals of those programs. The goals may not be attainable without the cooperation of employees, but only management has the authority to request of its employees the actions needed to realize those goals.

Commitment provides a sense of purpose, identity, and direction to those responsible for managing a company. This commitment must be highly visible and effectively communicated to all rank and file workers. It must be genuine and backed by the highest levels of company management, including the chief executive officer and the board of directors or owner. It must be accompanied by actions that convince everyone in the company of the sincerity of the commitment. However, commitment can create only an illusion of accomplishment unless it results in action. Below are six actions that illustrate what commitment can represent; they by no means exhaust the possible examples.

1. A written policy statement is developed by the key executives that clearly states the company's commitment to safety in the production of coal. Along with the policy statement, a plan is developed to implement and carry out the policy. The policy statement is circulated widely, displayed prominently, and given to all employees, especially new employees.

2. An executive position equivalent in rank and authority to other essential positions within the company is created and given the responsibility for safety.

3. Managers are evaluated on the basis of safety as well as production. Advancement and compensation are based on their overall performance.

4. The company develops an effective safety program in which it is willing to invest funds, personnel, time, and other resources.

5. The company develops and uses special safety training programs for young workers.

6. All supervisors, particularly foremen, enforce safety rules strictly and set the proper example by their own behavior.

The statistical analyses (Chapter 4) conducted as part of this study show that the important reasons why some companies have better safety records than others are not due to physical, technological, or geographical conditions, but are internal to the companies themselves. This strongly suggests that the commitment and dedication of top management are important factors in the differences between company safety records. Case studies (Chapter 4) and mine visits (Chapter 5) show that companies with consistently good safety records, and companies with improving safety records, have demonstrated that committing management at all levels to the safe and productive operation of underground mines can lead to superior or greatly improved safety performance.

The importance of management's commitment to safety was repeatedly emphasized to the Committee by leaders of labor, industry, and government who appeared and presented their viewpoints on mine safety. A top union safety official, commenting on factors that influence safety, said, "When a company's top management is determined to have safety, the results show it; the attitude of top management is apparent in every one of their mines." A company chief inspector for coal mining, listing the principal reasons for his company's good safety record, noted, "Every member of management is responsible for safety." A Mine Safety and Health Administration (MSHA) district manager, commenting on variations between companies with regard to safety, felt that these were not due to the geology of the mines: "The attitude of the company is of prime importance." The director of a coal research institute, in ranking factors that characterize safer mines, first listed "the strong involvement of company management." A vice president of engineering, when asked what makes a good mine, responded, "It is management being willing to accept responsibility. Awareness of safety must come from the highest levels of the company."

Similar opinions were stated by miners, supervisors, and safety directors during the course of our visits to 12 underground coal mines (the reports of those visits appear in Chapter 5).

B. Cooperation Between Management and Labor

On many issues the relationship between labor and management has been, and will continue to be, adversarial. But on safety matters, even when these impinge on issues that are normally the subject of collective bargaining, cooperation becomes imperative. The primary responsibility for complying with safety regulations, as well as for developing an effective safety program, must rest with management. But the efforts of management can be either frustrated by recalcitrant workers or augmented by cooperation.

John Maynard Keynes, the British economist, wrote that the difficulty in adapting to changing economic conditions is not so much accepting new ideas as giving up old ones. Similarly, if the safety record of underground coal mining is to be improved, old work habits must be discarded and new, safer work habits must be accepted by all miners. The best safety program in the world, developed by the most committed management, will work only if it has the wholehearted support and active cooperation of those who actually mine the coal.

To have a positive attitude toward safety, workers must recognize management's commitment to their physical well-being and be willing to toe the line on safety rules. A positive attitude toward safety frequently requires breaking old habits. Workers frequently exposed to danger may become careless and unconsciously discount the risks involved. Every miner knows the danger of going under an unsupported roof, but this is where accidents from roof falls typically occur. Management must be willing to discipline foremen who fail to discipline miners for violating safety rules. If the mine is to be safe, moreover, workers must accept the fact that safety violations are legitimate causes for discipline. Safety directors and other officials in companies with low accident rates maintain that the attitude of the workers is one of the important factors in making a mine safe.

The Committee in its visits to 12 underground coal mines found that differences in injury rates are due in part to the degree of a company's cooperation with employees in its mines. At the six mines with low injury rates that were visited by committee members, good relations between management and labor were apparent and were considered by the employees as being important to safety. Among the commonly recognized elements of these relations were an open-door policy at the manager's office and a willingness to accept suggestions regarding safety. At these mines the union generally supported the company's enforcement of safety rules.

Three of the other mines visited had formerly poor but improving safety performances. Changes in local management or ownership at these mines had brought better relations and communication.

The remaining three mines that the Committee visited had relatively high injury rates. At one of them labor relations were specifically noted as being poor, with strong union opposition. At the second there were poor labor relations, but the union was not particularly uncooperative. Labor relations were good at the third, but communication with the workers was poor, particularly with regard to safety.

C. Education and Training

The majority of managers, supervisors, and workers we talked to agreed that education and training of workers and supervisors before entering the workforce and while on the job is highly beneficial to safety.

Of the companies we studied, the ones with the best safety records also stand out in terms of their emphasis on education and training. Some of these companies have established well-equipped training facilities for initial training, for continuing training and education, and for more specialized training. Other companies use local community colleges or other training facilities. Some companies help local community colleges develop mining technology programs by providing financial support and teaching staff. Some company programs offer training far beyond job safety procedures, including education in labor-management relations, leadership, corporate structure and goals, and other subjects. One of the companies we visited had doubled the required 40 hours of training for beginning miners. Some companies have developed release-time programs to send new miners to school for training.

On the other hand, some companies seem to find it hard to use the 90 working days of orientation time (which, for instance, Kentucky prescribes for new miners) in a meaningful way. New miners eagerly wait for this period to end so that they can start learning how to operate shuttle cars, continuous miners, and roof bolters. Our own analyses (see "Age of Miner" in Chapter 4) indicate that younger miners have proportionally far more injuries than do older miners. While this strong association does not prove that better education and training are essential to safety, it does demonstrate that the potential for improvement is greater among young and inexperienced miners.

Galloway and McAteer have shown that training to become a miner in other countries is much longer, is frequently more formal than in the United States, and requires a general education at an entry level (see "Comparison of U.S. Underground Coal Mining with Practice in Other Countries" in Chapter 3). Although part of the lower fatality rates in these countries is likely due to differences in mining conditions and equipment, we feel that a substantial portion may be due to better education and training.

II. THERE IS A STRONG CORRELATION BETWEEN AGE AND DISABLING INJURIES IN UNDERGROUND COAL MINES

The injury rates of miners 18-24, 25-34, 35-44, and 45+ are 20.3, 11.5, 9.2, and 6.5, respectively.* Thus a miner between 18 and 24 is about three times more likely to be injured than is a miner over 45, and about twice as likely to be injured as is a miner between 25 and 44. This association was apparent in each of the 15 coal companies for which we had age distribution data.

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*"Injury rate" refers to the average number of disabling injuries among 100 miners during the course of a year; it is defined more precisely in Chapter 4.

This finding does not explain why some underground coal mines are safer than others, but it does indicate, beyond doubt, that companies that wish to lower their injury rates should concentrate on the younger miners.

On the basis of the kind of data available to us, it was not possible to determine precisely how much of the association between age and injury rate is due to age itself, to type of job, or to a miner's experience at a particular job or mine. It is likely that each of these factors influences the propensity for being injured, but to what extent can come only from data giving the distribution of job type and experience across the industry, information that was not in the data base. In any case, the correlation of injury rate with age is clear and indisputable; younger miners have a higher injury rate. However, there is no evidence of an age trend with respect to fatality rates (see "Age of Miner" in Chapter 4).

III. THERE IS A STRONG CORRELATION BETWEEN MINE SIZE AND FATALITIES IN UNDERGROUND COAL MINES

The President's Commission on Coal noted that during the period January 1978-June 1979, underground coal mines employing 50 or fewer employees accounted for 15 percent of underground work hours but for more than 40 percent of all underground fatalities.

Our findings corroborate and extend those of the President's Commission. Between 1978 and 1980, mines with 50 or fewer employees had a fatality rate nearly three times that of mines with over 250 employees, and almost twice that of mines with 51-250 employees. Moreover, this association is consistent in all the MSHA data we examined back through 1970. It could not be explained by differences between small and large mines with respect to location (state), seam thickness, or any of the other factors we examined in our analysis (Chapter 4).

As shown in Chapter 4, the distribution of fatalities with respect to types of accidents is similar for the various categories of mine size. This means that the increased fatality rate in small mines is not due to an increase of a particular type of fatal accident (such as roof falls) relative to larger mines. Rather, smaller mines have proportionally more fatalities than do larger mines within each of the major categories of accidents that cause fatalities--namely, roof and rib falls, explosions, electrocutions, and machinery and haulage accidents. These are the types of accidents that the Mine Safety and Health Act of 1969 and its enforcement were intended to reduce through creation and enforcement of standards for stricter roof control, better ventilation, better protection of machinery operators, and better maintenance of equipment. Since 1970 the fatality rates for each size category have declined considerably, yet small mines have consistently had larger fatality rates than have large mines.

One possible explanation of the correlation between mine size and fatality rate is that in large mines there are proportionally more miners away from the working face and thus at lower risk. If this were the case, larger mines would tend to have lower fatality rates than smaller mines even though the risks for miners near the face were similar for the two groups. This explanation seemed plausible to the Committee; however, the observed association between mine size and fatality rate is so strong that this phenomenon could explain only a portion of the association (see "Mine Size" in Chapter 4).

OTHER CHARACTERISTICS ASSOCIATED WITH UNDERGROUND COAL MINE SAFETY

Several other characteristics were analyzed in our study but were found to be less important to an understanding of coal mine safety than company differences, miner age, and mine size (see "Correlates of Injury Rates" in Chapter 4). Nonunion mines overall have twice the fatality rate of union mines; however, this difference can be fully explained by differences in mine size between union and nonunion mines. Union mines have a somewhat higher disabling injury rate than do nonunion mines, but closer inspection of the data suggests that this is largely a reporting phenomenon. Clear differences in fatality and injury rates emerge between the states with underground coal mines. Among the seven largest producers--Alabama, Illinois, Kentucky, Ohio, Pennsylvania, Virginia, and West Virginia--the disabling injury rate in Kentucky has been considerably lower than in the other states. The fatality rate in Virginia has been larger than that of other states; this difference is due in part, but not entirely, to a greater proportion of small mines in Virginia than in other states.

Overall, mines with higher productivity have lower injury rates than do less productive mines. This positive association between productivity and safety is attenuated after adjustment for other mine characteristics, but nonetheless it demonstrates that productivity and safety are compatible qualities in underground coal mines.

Finally, seam thickness, a factor related to geological conditions, has only a weak association with injury rate. Mines having a seam thickness of 48 in. or less have slightly higher fatality rates than do mines with seam heights over 48 in. But this difference is accounted for by mine size; the mines with thinner seams are generally smaller mines, and as we have seen smaller mines have higher fatality rates.

2

OPTIONS FOR ACTION

This chapter addresses the second major question to which the Committee directed its attention, "What can be done to make U.S. underground coal mines safer than they are today?" We have organized our answers around the three principal reasons that we believe explain why some U.S. underground coal mines are safer than others--namely, management's commitment to safety, the degree of cooperation between management and labor, and the quality of education and training. We have organized our discussion with respect to these reasons around the contributions that the private sector (management and labor) and governments (federal and state) can make to achieving better safety in underground coal mines.

OPTIONS FOR THE PRIVATE SECTOR

A. What Can Be Done to Foster Management's Commitment to Safety?

The principal motivations to enhance management's commitment to safety must come from within the company. External inducements cannot substitute, although they may fortify and enhance a company's determination to improve its safety record. With that purpose in mind, we recommend the following three options.

1. Encourage industry leaders to reinforce the value and importance of safety. Ideally, management's commitment is internal; saving lives and minimizing injuries are deeply held social values. However, it may be necessary from time to time for industry leaders to remind their peers that safety is as important a value to uphold as is

producing coal at the lowest cost per ton. Internalization of values is reinforced by the opinions of value leaders. We therefore encourage those chief executives and corporate officers of high stature in the industry to speak up at industry conferences and in trade publications, to bear witness to the importance of the value of mining coal safely.

2. Encourage publication of annual rankings of companies by their injury rates. We have seen evidence that publication by the President's Commission on Coal of the rankings by injury rates of the 20 largest companies had a perhaps unintended influence--namely, managers of these companies were concerned as to their standing relative to other companies with respect to safety. Embarrassment from being placed on the lower half of such a ranking could be an inducement to the managers of such companies to try to improve their standings. The statistical analyses in Chapter 4 include refinements of analytical techniques that reduce the likelihood that managers will dismiss such results by refuting the analysis. Our results show verifiable differences between companies. Since this information is available to the public, we recommend that one of the existing industry associations obtain data from the Mine Safety and Health Administration (MSHA), use proper statistical methods, and publish the rankings of companies periodically (quarterly or annually) to focus attention on safety.

3. Publicize the evidence that productivity and safety can be positively related. The Committee realizes the importance of supplementing attempts to internalize the value of safety with external inducements. There is a widespread belief among industry management that safety and productivity are inversely related--that the more time and resources are devoted to safety, the less they are available for production, or that specific procedures implemented to improve safety reduce productivity. This belief is contradicted by the analyses carried out by the Committee; these analyses show that more productive mines can be safer mines (see "Productivity" in Chapter 4). Although it is possible that one specific safety procedure considered in isolation may appear counterproductive, comprehensive safety programs tend to be associated with productive mines. The common denominator in such cases is competent management. A management that can plan well to increase production can also plan well to improve safety.

Moreover, a management that shows concern about safety signals to its employees that it is concerned about their well-being and thus deserves their contributions of skill and energy in improving productivity. Finally, a management that is willing to listen to employees' ideas for improving safety (which we found associated with effective programs) is also likely to listen to employees' ideas for improving productivity. The Committee strongly encourages managers of companies with both good safety and good productivity records to publicize this to their peers at industry conferences. We further encourage the editors of industry magazines to publish stories about such managers and their experiences.

B. What Can Be Done to Encourage Cooperation Between Labor and Management?

The following recommendations are made within the context of cooperation between management and an organized workforce. However, the same recommendations can apply to cooperation between management and unorganized employees. The 1981 National Bituminous Coal Wage Agreement provides for the establishment of several committees at each mine through which the local union and mine management can discuss safety. For nonunion employees, management can take the initiative to set up employee committees through which suggestions for improving safety can be solicited. However, provisions to establish these committees do not guarantee that they will meet or that they will focus on subjects with which the committees were intended to deal. Companies with good safety records use these committees in a creative and effective manner.

Both management and labor must take the initiative to improve the climate of trust between them as a first step toward cooperation. Joint labor-management safety committees at each mine (within an agreement negotiated by labor and industry in unionized mines) may be one way to encourage such cooperation. In United Mine Workers mines, it can also be developed under Article III, Section d(6), of the 1981 National Bituminous Coal Wage Agreement. Management and members of the health and safety committee need to make mine visits and inspections together as well as collect pertinent information. They need to develop plans and goals together; plans and goals developed jointly can encourage the union and management to think about what they can do together in the future, stemming the conflict over what each party did or did not do about safety in the past. Neither party should expect a quick solution or magical turnaround; a year or more is not an unrealistic period for union and management to change adversarial attitudes into cooperative ones.

Labor-management cooperation can also be fostered when employees and union officers participate in the development of safety programs. Article XVI, Section g(2), of the 1981 contract permits the union only to review training programs that management has developed. If employees or their representatives have not been involved in a program's development, they can respond only in a limited way; their ideas and cooperation have not been encouraged.

C. What Can Be Done to Achieve Higher Quality Education and Training for Employees and Managers?

The majority of the managers, supervisors, and workers we talked with agreed that education before and after entering the workforce is highly beneficial. The Committee believes that a greater emphasis on education in the coal industry is needed and that it would substantially improve safety.

Most companies prefer to hire better-educated people as new employees. Companies therefore should be interested in good mining technology programs at community colleges and in mining and geological engineering programs at universities. They should consider supporting such programs more systematically than they do now. Trade associations, such as the National Coal Association or various state coal associations, might provide a vehicle for such systematic support. Concurrently, establishing minimum educational requirements for certain jobs should be considered. Some companies have already established such requirements internally.

An outstanding characteristic of foreign mine safety education is the use of underground training faces, which in some cases do not produce coal and in others do so only to the extent that practice on the equipment allows. Some American companies that have training faces are Old Ben, Jim Walter Resources, and Clinchfield. Such faces are used as a practical introduction for all underground coal miners.

A major upgrading of the educational and training requirements that new and experienced miners, and also supervisors, must meet is required if we are to contemplate any substantial improvement in the safety of U.S. underground coal mines. In coal mining productivity, the United States compares favorably with all other nations, but in the education and training of its coal miners and supervisors the United States lags behind such nations as Great Britain, Germany, and Poland (see "Comparison of U.S. Underground Coal Mining with Practice in Other Countries" in Chapter 3).

OPTIONS FOR THE FEDERAL GOVERNMENT

Laws and regulations requiring affirmative compliance with safety standards are vital to maintaining and improving safety in underground coal mines. Enforcement of safety standards and continuing improvement of safety regulations are a necessary part of the overall foundation of a national commitment to improved underground coal mine safety. No compromise or dilution of the government's regulatory role is justified by any evidence considered by this Committee. However, government can contribute to achieving the recommendations made in this report in a number of ways.

Provide Consultative Services

Government could contribute significantly by offering increased consultative activities that support and encourage companies to implement the recommendations of the Committee.

First, the federal government can place additional emphasis on the establishment or improvement of company safety and training programs. Statutory authorization for such activity already exists in Section 502(b) of the 1977 Mine Safety and Health Act. A consultative arm, not associated with the inspection and enforcement activity but dedicated to assisting companies with their overall safety and training programs, could be developed from personnel presently available. Its mission would be to assist companies in developing effective safety and training programs, to keep abreast of the state of the art in safety, and to disseminate that information effectively. The essentials of good safety management--promoting and teaching increased safety awareness throughout the company --should be emphasized. A relatively small number of individuals with expertise could serve the companies, giving priority to those with poor safety records. Moreover, this is an area where private consultants who have proven credentials and a record of correcting weak safety and training programs could be used effectively.

Virtually every individual and group appearing before the Committee stressed the importance of attitudes and human behavior--the human element--in preventing accidents, as well as the need for heightened safety awareness, education, and training. It is in such areas that assistance to companies would be concentrated under the proposed program. Safety training and safety programs tailored to the human element should be emphasized and encouraged by government.

Second, present consultative activities of MSHA should be expanded in another direction explicitly authorized by Section 502 of the 1977 act--namely, the availability of technical assistance to mine operators should be increased so that they can meet the requirements of the act. However, this technical assistance should be furnished by a part of the agency outside the normal inspection and enforcement operations of MSHA. The primary role of the MSHA inspector in the field is to ensure compliance with the law. Imposing on inspectors the requirement also to furnish recommendations on how to achieve compliance with particular standards would create several problems. First, imposing such a dual responsibility on field inspectors could dilute enforcement responsibilities; and, second, such a dual role would be difficult to monitor, organize, and control. Because conditions vary within a particular mine on a daily basis, misunderstandings and inconsistencies in the advice given by different inspectors at different times would arise.

Expansion of the technical assistance program currently operating in MSHA would be a tangible demonstration by the government of its encouragement of increased management commitment to safety. An expanded consultative arm would be more generally available for advice regarding serious compliance problems faced by mine operators. Such advice should prove particularly helpful in achieving compliance with performance standards, which do not specify the precise measures required by the regulation but require a certain result. Mine operators in need of such assistance would have a tangible point of contact within the agency to which they could be referred, and this part of the agency should be staffed and funded to provide a substantial range of advisory assistance. In this manner, there would be little or no risk of compromising the necessary enforcement role of government while promoting increased safety.

Provide Tax Incentives

Investment tax credits designed to induce the private sector to work toward socially desirable objectives are well established in the United States. One of the better known is the use of accelerated depreciation to stimulate investment in plants and equipment during periods of economic recession. Regional development programs, such as those of the Economic Development Administration, have also used investment tax credits as a positive inducement for management to locate new plants in areas with surplus labor.

The dominant theme of this report is that an effective safety program requires a strong commitment to safety by top management. The evidence presented to the Committee shows clearly that this commitment exists in some companies. One of the recommendations of this report is that companies with less safe mines should attempt to emulate the practices of companies with outstanding safety records. Granting companies a tax credit for approved safety expenditures might be an additional inducement for them to make the investments needed to improve safety.

The feasibility and details of a safety tax credit program would have to be studied and developed by the appropriate congressional committees. For instance, they might consider tax credits for special items purchased in behalf of safety beyond what is required by law. The list of items should be uniform throughout the industry. The total dollar cost of these items could be the basis for a federal tax credit. Some areas of activity that might also qualify for tax credits are roof support, fire prevention, inspection, training, and education.

The United States now has legislation requiring compliance with existing safety legislation. We offer the suggestion of tax incentives to Congress--which alone has the power to grant federal tax credits--as one way to induce the management of coal companies to make the total commitment to safety needed to reduce hazards in one of the nation's most dangerous industries.

Increase Training Requirements

The federal government should increase the minimum requirements for the training of new miners. Requirements for formal education have been the subject of various state mining laws for several decades, but these have varied markedly from state to state. The Mine Safety and Health Act of 1977 prescribed minimum requirements for safety training that are uniform nationwide. These requirements are being met, at least by the large coal producers; the Committee found no failure to comply in the dozen or so companies examined in its study. Some companies provide little more than the minimum, but those companies cited in this report for their good or improving safety records do provide their employees, in varying degrees, with more, some with considerably more, than the required minimum safety education.

The Mine Safety and Health Act of 1977 requires only 40 hours of training for new miners (of which approximately 8 hours shall be at the mine site). This training must be done by instructors certified by MSHA and must conform to a training schedule prepared by the company and approved by MSHA.

Each of the 14 topics in the training schedule is important, but an adequate coverage of each is hardly possible within a 40-hour program. At some mines any one of several topics, such as ventilation or emergency evacuation, may be much more complicated than at another mine, thus requiring much more attention than the minimum. New miners are not required to receive familiarization training on various pieces of heavy equipment until they are ready to be assigned to work with a particular unit. Such lack of knowledge can be dangerous in an emergency.

These considerations call for a major increase in the time allotted to initial training, with a suggested minimum of an additional 40 hours. Furthermore, explanation, demonstration, and practice in application must be followed by some form of evaluation. For example, the entering miner might be required to pass a written and a practical examination in the various subjects before beginning to work in a mine.

The regulations prescribe that additional training shall be given to newly employed, experienced miners, to miners assigned to a task for which they have not been previously instructed, and to all miners as an annual refresher. The presently prescribed topics should be continued or expanded as appropriate, and the minimum number of hours of training should be specified for each of these groups after carefully considering the special conditions of the mine involved.

Improve Reported Safety Data

The government could substantially improve the information it collects routinely for the analysis of safety in U.S. coal mines. MSHA collects very detailed information about the characteristics of miners involved in accidents and about the resulting injuries. However, much of this information cannot be properly interpreted without corresponding information about the characteristics of all miners. For example, the demonstration of a strong association between a miner's age and disabling injury rates requires a comparison of the age distribution of accident victims with the corresponding distribution of all miners. MSHA collects information on the former but not on the latter. As a result, the Committee needed to carry out its own survey of company-wide age distributions to establish the association between age and injury rate. Data on the distribution of job types and job experience, were it available, might have identified the relative importance of age, job type, and job experience and thereby led to the development of more effective training programs. Other improvements in the kinds of data gathered by MSHA are possible. <u>We recommend that MSHA reconsider the kind of data routinely collected from mines with the view of improving analyses of the factors that contribute to mine safety</u>.

OPTIONS FOR STATE GOVERNMENTS

State laws on coal mine safety vary widely. In general, the laws are broader in scope and more detailed in those states where mining is a more important economic activity. We recommend that all states that now mine coal underground, or that reasonably expect to do so within a few years, pass laws (where none exist) or modify laws where necessary to establish educational and testing standards for mine officials and technicians and to provide for better organized and supervised apprenticeship programs for miners.

Education is largely a responsibility of state governments. In some states, vocational training in mining skills is provided at secondary schools and also at the junior or community college level. There are a few programs to educate mining technicians and mine safety technicians. Mining engineering education comes at the university level; of 15 states with underground coal mines in 1979, only 7 had accredited programs leading to bachelor's degrees in mining or minerals engineering. Three or four other states had started such programs that were not accredited at that time.

We recommend that the states establish programs for the vocational education of miners, mining technicians, and mine safety technicians. We also recommend that accreditable programs for degrees in mining engineering be established in states with underground coal mines that do not have such programs, or that arrangements be made for students to use the programs of neighboring states at the same cost charged residents of the host states.

3

BACKGROUND

INTRODUCTION

The prosperity of the United States depends, among other things, on adequate sources of energy. For the remainder of this century an increasingly important source of that energy will be coal. In 1980 coal supplied 18 percent of the energy used in the United States (26 percent worldwide). In the 1960s and 1970s most of the increase in energy demand was met by increased use of oil, but oil supplies will remain constant or diminish in the next two decades. Any future increase in energy demand will have to be supplied principally by coal (World Coal Study, 1980).

In the United States coal is an abundant and readily available fuel. Vast deposits underlie the mountains of Appalachia, extending from Pennsylvania through West Virginia to Alabama. Other deposits are found in Ohio, Kentucky, and Illinois and under the high plateaus of Montana, Wyoming, Utah, and Colorado. Coal is found in 36 states of the continental United States, and known reserves are expected to last for several hundred years. These are the reserves that the United States, and to some extent other nations, will have to draw on to supply one half to two thirds of the expected increase in energy use in the next 20 years, assuming only moderate economic growth. To satisfy this increased energy demand, coal production in the United States and abroad will have to increase two to three times during the next two decades (World Coal Study, 1980).

Nearly half of the electricity consumed in the United States depends on coal as a fuel. Coal is transformed into coke, an essential ingredient in steelmaking. Coal tars are an important feedstock in the chemical industry.

In industrial countries coal can become a primary fuel for economic growth and for the replacement of oil; in less developed countries it may be the only abundant fuel for electric power generation and industrial development.

Nearly one half of the coal mined in the United States comes from underground mines, and it is the safety of operation of these mines that is the principal subject of this report. The role of safety should be viewed in relation to a general background of the coal mining industry. In an effort to provide such a background, we will attempt to answer the following questions:

How is coal mined in U.S. underground coal mines and what geological considerations are important?

What is the history of injuries, fatalities, and disasters in U.S. underground coal mines and how does the United States compare with other nations in coal mine safety, training, and productivity?

How does the coal mining industry in the United States compare with other industries in terms of safety?

What is the history of mine safety legislation, at both the state and federal levels?

How is the U.S. coal industry organized, what is the economic value of coal, and what proportion of the gross national product does it constitute?

Who is the American coal miner, how and where does he live, how well is he educated, what is his status in society, and how does he differ from the image of the miner of previous years?

What is the history of labor organization in U.S. coal mining and how has it affected underground coal mine safety?

UNDERGROUND COAL MINING IN THE UNITED STATES

Mining Methods

The plan of an underground coal mine is similar to that of a city where most of the traffic and utilities are carried on a few thoroughfares. In a coal mine these thoroughfares are called mains and submains. Each main consists of several parallel entries (passageways or tunnels) supported by pillars of coal and interconnected by other passageways called crosscuts. The pillars between the entries are thus generally rectangular in plan. Because the mains and submains provide access to the working places for electric power, water, ventilating air, communications, and transportation facilities for the coal, men, and supplies, they have to be kept open and maintained until the areas of the mine they serve have been mined out. The working areas are called panels and have to be maintained only as long as they are being mined.

Panels are mined either by the room-and-pillar method or by the longwall method. (Shortwall mining can be considered a variation of longwall mining.) In the United States more than 90 percent of the coal is mined by the room-and-pillar method; in Europe and Great Britain almost all coal is mined by the longwall method. Room-and-pillar mining is further classified as conventional or as continuous, depending on the equipment used to mine the coal. In conventional mining the production cycle consists of cutting, drilling, blasting, loading, hauling, and roof bolting. In continuous mining one machine, called a continuous miner, is used to accomplish the cutting, drilling, blasting, and loading steps in the cycle (see Figure 1).

In room-and-pillar mines the coal is mined by a grid of rooms and crosscuts that may vary from 14 to 25 ft in width (see Figure 2). The pillars that remain may range from 20 to 90 ft on a side. After a panel has been mined by this method, the pillars in the panel may themselves be extracted on the retreat from the panel if subsidence of the ground surface is allowable.

In longwall mining the panels range from 300 to 700 ft wide and from 1,500 to 8,000 ft long. In the United States panels are developed by sets of entries driven by continuous miners and then mined on the retreat (see Figure 3). On the longwall the coal is mined by a special mining machine (a shearer or a plow) that cuts slices along the short end of the panel (called the longwall face). This coal is then transported to one end of the panel, the headgate, by a chain conveyor. Roof control is by hydraulically operated roof supports, which provide a narrow canopy of support along the coal face. The roof supports (chocks or shields) protect the miners, the mining machine, and the chain conveyor from caving rock. They are moved in conjunction with the mining machine so that the supports provide protection as close to the face as possible. The roof rock caves behind the supports as mining progresses (see Figure 4).

Longwall mining allows the recovery of about 90 percent of the coal in place, as compared with about 70 to 80 percent in room-and-pillar mining with pillar extraction

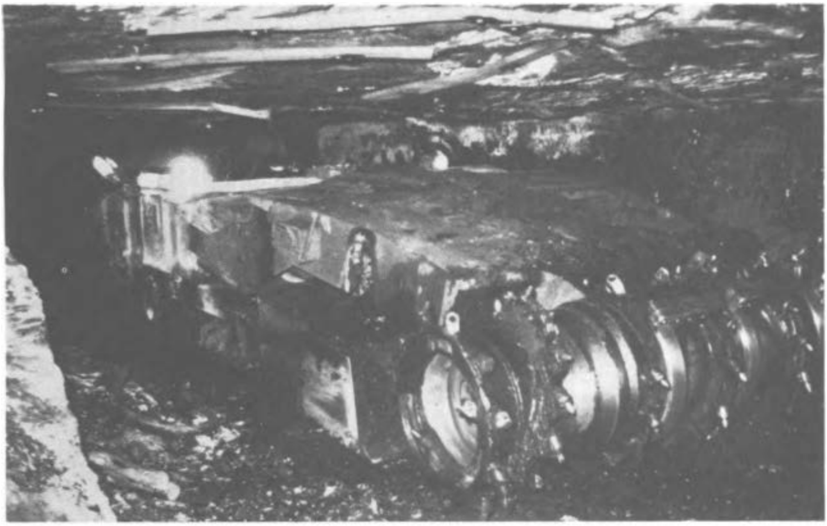

FIGURE 1 A Lee-Norse continuous miner in operation.

and 45 to 60 percent without pillar recovery. Longwall mining also permits a high extraction ratio at great depths, whereas room-and-pillar mining becomes difficult and uneconomic at depths much below 1,000 ft because of high pressures on the pillars. A longwall face is also safer than other faces because miners work under full steel canopies and can perform many operations by remote control. Another advantage of longwall mining can be improved productivity in terms of tons per man-shift. Disadvantages of longwall mining include a much higher initial cost for equipment and the possible necessity of purchasing from landowners the right for the surface to subside. Another disadvantage is that it is less flexible than room-and-pillar mining, so there are places where it is impractical or difficult to use.

Roof Control

When large areas of a coal seam are mined, the only way to prevent surface subsidence is to leave pillars of coal that are strong enough to withstand the pressure caused by the columns of rock that rest on them. Pillars are thus used to control subsidence and major movements of the

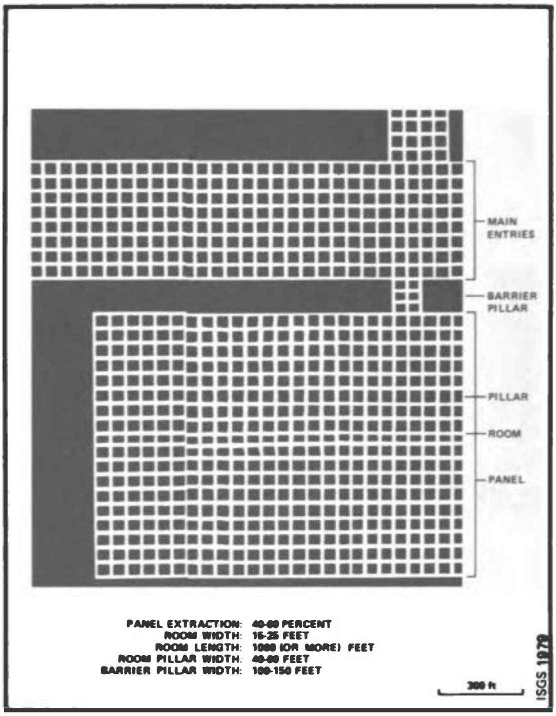

FIGURE 2 Room-and-pillar mining produces evenly spaced large square pillars in a checkerboard configuration (after Hunt, 1980).

overlying strata. The mined-out space between pillars must be kept open for a long period of time. Coal mine roof rocks, however, are generally weak rocks, so in addition to pillars other means of roof support are usually required to prevent caving or local falls of rock between pillars. Various types of artificial supports are used for this purpose. In room-and-pillar mining, roof bolting is used most widely, with more positive types of support, such as cribs, timber posts, and screw jacks, being employed if additional support is necessary. To install a roof bolt, a hole is drilled in the roof rock and the bolt is anchored in the hole using an expansion shell or is cemented in the hole with resin. Often this

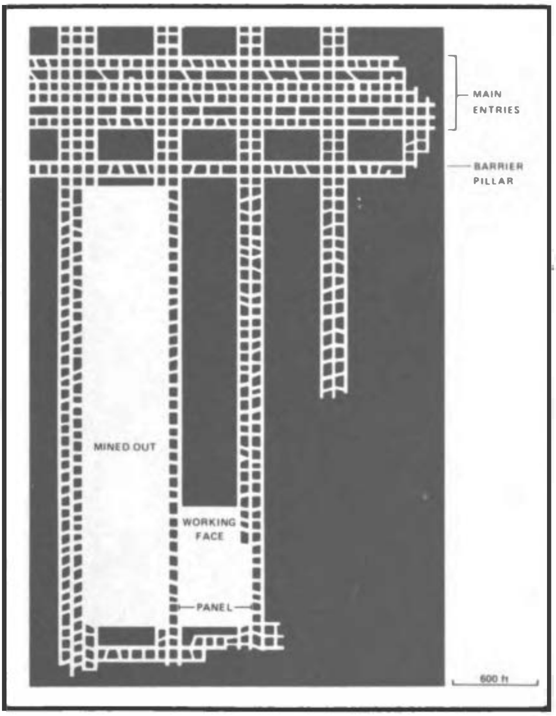

FIGURE 3 General development plan for high-extraction retreat and longwall mining (after Hunt, 1980).

operation is performed by a roof-bolting machine, sometimes with an automated temporary roof support (ATRS) device attached (see Figure 5).

In longwall mining the roof at the working face is supported by the advancing hydraulic supports, and the unsupported roof behind the supports falls as the mining machine and the supports are advanced. In longwall mines in the United States the roof supports in the mains, in the submains, and in multiple entries between panels are the same as those used in room-and-pillar mines. In Europe, where only single entries are mined between panels, positive types of support, such as steel arches or deformable steel sets with wooden lagging between them, are generally used.

FIGURE 4 An illuminated longwall face at Greenwich Collieries near Cookport, Pennsylvania.

Transportation Methods

The broken coal at the working face is transported to the preparation plant or to other facilities on the surface by a variety of methods. In room-and-pillar mines shuttle cars (underground electric or diesel trucks) are used to transport the coal from the face to an intermediate transfer point in the panel. In longwall mines a chain conveyor is used to transport coal along the face to the headgate within the panel. Conveyors are used for transportation from the end of the haulage system at the face to the haulage system in the mains and submains. This main haulage system may use conveyors or trucks on tracks. Transportation to the surface may be by a direct route for a drift mine, where the coal outcrops on the side of a hill or mountain, by a slope with a conveyor or an inclined hoist for relatively shallow deposits, or by a shaft hoist for deep mines.

Transportation of men and supplies underground is usually by rail, but rubber-tired vehicles are also used.

Ventilation

All underground mines are ventilated by large fans that provide great volumes of air to dilute and remove methane gas and dust. The fresh air that arrives at a working place is called intake air. It dilutes and removes the dust created by the mining operation and the methane that is liberated. This air is removed through other passageways called the return airways. Each working section must be ventilated by a separate split of intake air. Thus in any coal mine there are at least two separate sets of airways, the intakes and the returns. In the United States, but not in other principal coal-producing areas of the world, the law states that conveyor belts must be on a neutral split, so in this country three separated sets of airways are required.

FIGURE 5 A Lee-Norse TD-2 roof bolter with automated temporary roof support (ATRS) in use at the Homer City Mine in Pennsylvania.

GEOLOGY

The underground coal miner works totally within a geologic environment. The roof above his head, the floor beneath his feet, and the coal seam from which he earns his living are all geologic strata. The thickness, depth, pitch, strength, stability, water and gas content, composition, and structure of these strata all result from geologic processes. Thus knowledge of the geology of a mine property is needed to operate a mine safely.

The voids that are created by the extraction of coal at depths of hundreds of feet, or even several thousand feet, are inherently unstable. Only the strength of the rocks above and below the coal seam, and of the coal itself, prevents the immediate collapse of the opening created by the partial removal of the coal. The inherent strength of the rocks depends on many factors. More highly indurated (i.e., hardened) rocks, those formerly buried more deeply, generally are stronger. At a given degree of induration, massive rocks of sandstone, siltstone, and limestone are the strongest, while shaly rocks with more or less parallel, closely spaced separation surfaces created during sedimentation in thin layers are the weakest.

In addition to the induration and type of rock, the character and degree of deformation greatly influence the overall strength of rock. Deformation can happen before burial while the sediments are still soft. After that it can occur by slumping of as yet unconsolidated sediments at depths of a few feet to tens of feet, by differential compaction of different sediments during further burial, by the formation of joints as burial increases, by folding under pressure, by fracturing or faulting under pressure or tension, and finally by the formation of fissures during millennia of erosion. Many structural features impart weakness to rock and coal. A large portion of unintentional roof falls occur where structural defects are encountered during room-and-pillar mining. While some of the structural defects are fairly predictable, if the local geology is well understood, others are essentially unpredictable and must be recognized and dealt with as they are exposed during mining.

In a room-and-pillar underground coal mine the naturally formed rocks, with all their inherent variations and deformation, become part of the underground mine structure. Unlike the architect, who can chose his materials, the mining engineer must take what nature offers and improve on it with an appropriate ground control system to prevent collapse of mine openings. A roof control plan is developed, based on knowledge gained during exploratory drilling or during previous or test mining, to reinforce the natural roof enough that the mine opening will remain stable for the required duration.

However, during the normal mining cycle in standard room-and-pillar mining, newly exposed roof could remain uncontrolled for several hours, i.e., the time usually needed to mine about 20 ft of coal (the length of a continuous miner) and move the mining machine out and the roof-bolting machine in. This is a critical period. A weak roof, or structural defects, could lead to roof failure during this interval before the roof bolting is started on or completed. Most fatalities by roof falls happen during this critical time interval. About one third to one half of the fatalities in underground coal mines are caused by failures of the roof, many before or during bolting. However, it has been pointed out (Price and Nolting, 1948; Maize and Wallace, 1956; Barry and Associates, 1971) that at least half of all roof fall fatalities have involved miners who were working under an unsupported roof or a roof with improper temporary supports despite state and federal regulations forbidding them to do so.

Mine gas (methane) comes from the formation of coal from peat under thousands of feet of sediments; peat is transformed into lignitic, subbituminous, bituminous, and finally anthracitic coal. The prime coking coals (bituminous coals of medium and low volatility) and anthracites form especially large quantities of methane. Coal has the capacity to hold significant quantities of gas adsorbed to its large internal surface area. This type of storage--adsorption to internal surfaces rather than retention in pores under high pressure--and the low permeability of coal make removal of mine gas before mining difficult. Much of the gas is released only as the coal is broken into very small pieces during the mining process, especially in very deep mines.

Mine gas is unevenly distributed, depending on the regional and local geologic structure. The U.S. Bureau of Mines has greatly added to our knowledge of its distribution and the nature of its occurrence. Though techniques to remove the gas before mining have been developed, the principal way of controlling mine gas remains dilution in ventilating air.

Other hazards in underground mines closely related to geology include coal outbursts, flooding or water seepage (which weakens the roof and produces a slippery floor), mine fires by spontaneous combustion, squeezes of the floor, and variable and sometimes steep gradients.

HISTORY OF FATALITIES IN U.S. UNDERGROUND COAL MINES

Table 1 gives the basic historical data on annual fatalities, employee-hours, and production in U.S. underground coal mines. These data were obtained from the Health and Safety Analysis Center of the Mine Safety and Health Administration (MSHA) in Denver. Some definitions are in order. Fatalities are those that occurred in underground coal mines; they do not include those that occurred in surface mining or those that occurred on the surface in connection with underground mining. To repeat, they are fatalities that occurred underground in underground coal mines. Similarly, employee-hours are the hours worked per year underground in underground coal mines. Production is the output of underground coal mines in short tons of coal per year.

Data were available from MSHA on disabling injuries over the 50-year period but were not used in this history. Changes in reporting requirements and in operators' compliance with these requirements have been so great over the 50-year interval as to cast doubt on the validity of any conclusions drawn from a comparison of injury data. By contrast, fatality reporting is considered reasonably accurate over the entire period and is therefore a better index of safety performance. The analysis in Chapter 4 is based on injury rates for the years 1978, 1979, and 1980, when the reporting requirements were unchanged and a high degree of comparability prevailed. Hence for those years (1978-80) disabling injury rate is a useful index of safety.

Table 2, derived from Table 1, gives annual fatality rates based on working time and on production. Also given is annual productivity, obtained simply by dividing the annual production by the annual employee-hours.

In Figure 6 the annual fatality rates based on employee-hours are given for the years 1931-80. Until the mid-1940s there were approximately 1,000 or more fatalities per year in U.S. underground coal mines, but the number of miners was two to four times as great as it is today. Nevertheless, the fatality rate was very high. Improvement occurred during the 1940s and 1950s with the introduction of mechanization, which had the effect of

TABLE 1 Fatalities, Employee-Hours, and Production in U.S. Underground Coal Mining, 1931-80

Years	Fatalities	Employee-Hours	Production (tons)
1931	1,378	748,942,825	416,718,433
1932	1,130	586,132,753	333,893,739
1933	976	663,298,411	356,359,179
1934	1,132	716,843,966	387,150,296
1935	1,144	686,631,907	392,504,706
1936	1,256	775,208,054	453,977,317
1937	1,318	767,651,412	457,991,826
1938	1,027	578,325,001	357,384,689
1939	1,014	631,174,468	401,942,282
1940	1,308	698,853,920	460,471,033
1941	1,166	759,404,938	502,018,940
1942	1,353	831,601,025	560,561,752
1943	1,327	821,831,745	556,266,384
1944	1,166	826,700,609	561,629,831
1945	960	723,548,050	502,489,349
1946	863	656,739,055	459,788,162
1947	1,047	712,134,852	530,913,345
1948	880	663,834,124	494,355,070
1949	508	470,728,130	357,550,429
1950	547	519,090,175	424,710,888
1951	707	511,978,524	444,005,016
1952	474	431,309,203	383,519,654
1953	409	369,242,524	367,327,424
1954	342	270,848,931	306,017,881
1955	352	294,013,251	359,612,537
1956	390	299,085,138	378,748,465
1957	424	280,614,185	370,683,866
1958	315	213,175,261	297,333,434
1959	251	192,630,346	293,291,026
1960	274	181,715,004	293,029,410
1961	256	163,106,195	279,595,340
1962	244	157,333,200	287,995,378
1963	245	159,240,677	308,711,417

TABLE 1 (Continued)

Years	Fatalities	Employee-Hours	Production (tons)
1964	210	161,043,446	328,331,873
1965	223	159,465,278	337,977,049
1966	194	154,002,624	342,325,509
1967	174	153,436,875	350,374,100
1968	268	148,593,131	344,630,387
1969	149	151,985,482	347,670,116
1970	206	164,576,129	339,562,040
1971	141	153,801,537	278,011,258
1972	122	170,495,460	287,714,237
1973	99	171,782,448	285,873,030
1974	90	173,409,396	263,962,854
1975	99	210,474,994	278,649,145
1976	104	217,941,158	281,031,488
1977	91	206,289,834	257,461,857
1978	67	193,794,718	229,075,592
1979	106	230,304,102	300,440,004
1980	94	222,870,843	321,018,628

increasing productivity and reducing the number of miners at risk. The fatality rate remained constant during the 1960s but soared in the disastrous year of 1968 to a level that had not been reached in almost 30 years. A major contributor to the 1968 fatality rate was the Farmington, West Virginia, disaster, in which 78 miners were killed. The Mine Safety and Health Act of 1969 has been considered by some a reaction to the 1968 fatality rate and to the Farmington disaster in particular. Regardless of what brought about the act of 1969, it appears to have had a dramatic effect in reducing underground coal mine fatalities. The fatality rate during the latter half of the 1970s was one third what it was in the 1960s and one fourth what it had been in the 1930s.

Figure 7 shows the fatality rate based on production and the productivity of U.S. underground coal mines. Productivity is defined as the tons of coal per miner work hour and is obtained by dividing annual production (the

TABLE 2 Fatality Rates and Productivity in U.S. Underground Coal Mining, 1931-80

Year	Fatality Rates: Per 200,000 Employee-Hours	Fatality Rates: Per 200,000 Tons of Coal	Productivity (tons per employee-hour)
1931	0.37	0.66	0.56
1932	.39	.68	.57
1933	.29	.55	.54
1934	.32	.58	.54
1935	.33	.58	.57
1936	.32	.55	.58
1937	.34	.58	.60
1938	.36	.57	.62
1939	.32	.50	.64
1940	.37	.57	.66
1941	.31	.46	.66
1942	.33	.48	.67
1943	.32	.48	.68
1944	.28	.42	.68
1945	.27	.38	.69
1946	.26	.38	.70
1947	.29	.39	.75
1948	.27	.36	.74
1949	.22	.28	.76
1950	.21	.26	.82
1951	.28	.32	.87
1952	.22	.25	.89
1953	.22	.22	.99
1954	.25	.22	1.13
1955	.24	.20	1.22
1956	.26	.21	1.27
1957	.30	.23	1.32
1958	.30	.21	1.39
1959	.26	.17	1.52
1960	.30	.19	1.61
1961	.31	.18	1.72
1962	.31	.17	1.83
1963	.31	.16	1.94

TABLE 2 (Continued)

Year	Fatality Rates: Per 200,000 Employee-Hours	Fatality Rates: Per 200,000 Tons of Coal	Productivity (tons per employee-hour)
1964	.26	.13	2.04
1965	.28	.13	2.13
1966	.25	.11	2.22
1967	.23	.10	2.29
1968	.35	.16	2.36
1969	.20	.09	2.29
1970	.25	.12	2.06
1971	.18	.10	1.81
1972	.14	.08	1.69
1973	.12	.07	1.66
1974	.10	.07	1.53
1975	.09	.07	1.33
1976	.10	.07	1.29
1977	.09	.07	1.25
1978	.07	.06	1.18
1979	.09	.07	1.30
1980	.08	.06	1.44

fourth column in Table 1) by annual employee-hours (the third column in Table 1). The figure illustrates the dramatic rise in productivity in U.S. underground coal mining in the 1950s and 1960s, which was due in large part to the mechanization of the mines and in particular to the introduction of the continuous miner. Until 1968 the fatality rate declined markedly as productivity increased, which should set to rest any belief that productivity and safety are incompatible. However, this does not imply a causal relationship between productivity and safety. After 1968, while the fatality rate continued to decrease, productivity decreased markedly, but it does not follow that decreased productivity was caused by the increase in safety (see "Productivity" in Chapter 4). The reader should note that after 1978 productivity resumed an increasing trend, thus reinforcing the positive relationship between productivity and safety that prevailed before 1968.

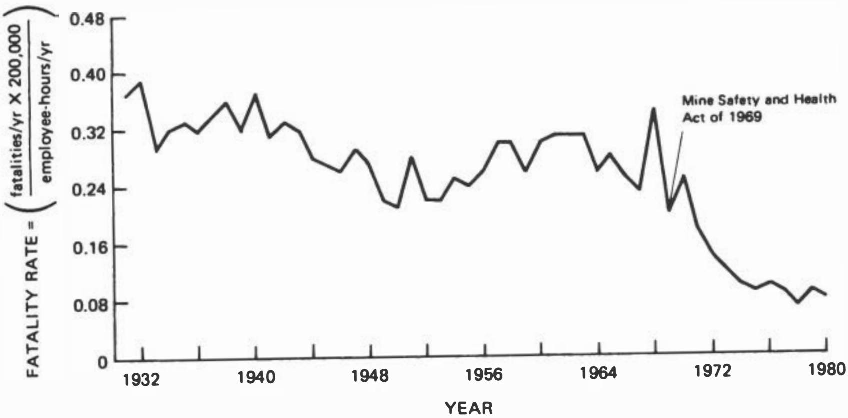

FIGURE 6 The fatality rate based on exposure in U.S. underground coal mines, 1931-80.

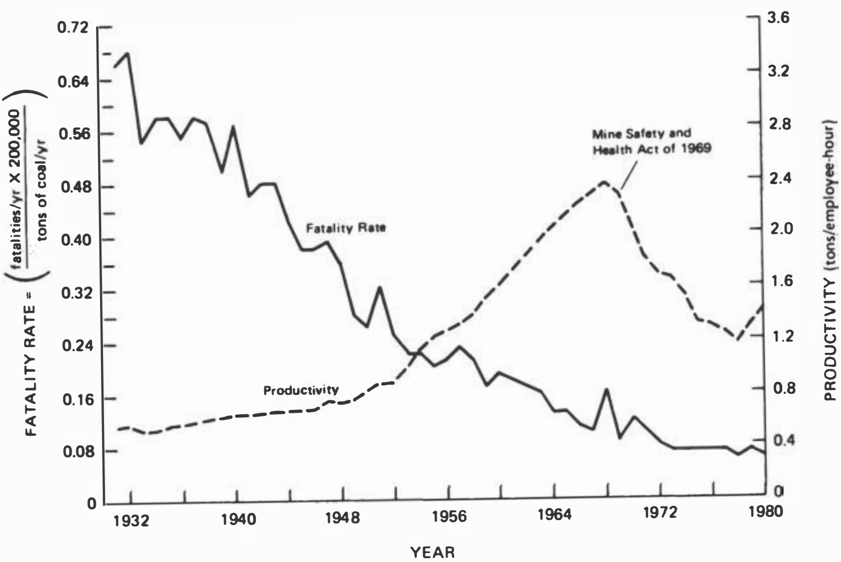

FIGURE 7 The fatality rate based on production and productivity in U.S. underground coal mines, 1931-80.

COMPARISON OF THE SAFETY OF U.S. UNDERGROUND COAL MINING WITH THAT OF OTHER OCCUPATIONAL ACTIVITIES

Data on occupational injuries and illnesses are collected and collated annually by the Occupational Safety and Health Administration (OSHA) and the Bureau of Labor Statistics (BLS) in accordance with provisions of the Occupational Safety and Health Act of 1970. BLS Bulletin 2097 (Bureau of Labor Statistics, 1981) gives occupational injury incidence rates by industry for the years 1978 and 1979. In addition, a BLS news release (USDL-81-526) gives data on occupational injuries for 1980. The incidence rates for coal mining were supplied to BLS by MSHA and are essentially complete (i.e., they include the total injuries reported to MSHA and the total employee-hours worked in coal mining). For most of the other industrial categories, the incidence rates were obtained by sampling and hence are subject to small sampling errors. Nevertheless, the data are considered suitable for comparative purposes by most labor statisticians and industrial planners.

The disabling injury rates for underground coal mining in 1978, 1979, and 1980 are given in Chapter 4 as 10.9 in 1978, 12.3 in 1979, and 12.7 in 1980. These numbers represent the lost workday injuries in a year per 100 full-time workers, or per 200,000 employee-hours. These rates are roughly three times the injury incidence rates for the private sector of the economy (see Table 3). They are more than twice the rates for manufacturing and for agriculture, forestry, and fishing, and are slightly less than twice the rates for all of mining and for all of construction. When one looks at smaller subdivisions of these major occupational categories, one finds occupations for which the injury incidence rates are comparable with those of underground coal mining. Examples are logging camps and logging contractors, sawmills and planing mills, construction of wood buildings and mobile homes, iron, steel, and nonferrous metal foundries, ship building and repairing, and meat packing.

When one considers the severity of occupational injuries, as represented by the number of lost workdays per injury, and also the fatality rate, underground coal mining emerges as one of the most dangerous, if not the most dangerous, occupational activity undertaken by a significant number of people in the United States.

TABLE 3 Occupational Injury Rates by Industry, 1978, 1979, and 1980

Industry	Disabling Injury Rate* 1978	1979	1980
Underground coal mining	10.9	12.3	12.7
All mining	6.4	6.7	6.4
Agriculture, forestry, and fishing	5.2	5.5	5.6
Construction	6.3	6.8	6.5
Manufacturing	5.4	5.7	5.2
All private sector occupations	4.0	4.2	3.9

*Based on cases involving days away from work per year per 100 full-time employees.

COMPARISON OF U.S. UNDERGROUND COAL MINING WITH PRACTICE IN OTHER COUNTRIES*

As mentioned previously, modern underground coal mining consists of variations of two general systems: room-and-pillar mining and longwall mining. Early in this century many variations of both systems were used in the United States and in a number of European countries, although longwall mining as practiced in the United States during the last century and early in this century differed substantially from modern longwall mining. By the late 1920s longwall mining had disappeared in this country while becoming the dominant system in Europe. Its reintroduction into the United States during the past two

*Parts of this section are condensed from J. Davitt McAteer and L. Thomas Galloway, "A Comparative Study of Miners' Training and Supervisory Certification in the Coal Mines of Great Britain, the Federal Republic of Germany, Poland, Romania, France, Australia and the United States: The Case for Federal Certification of Supervisors and Increased Training of Miners," West Virginia Law Review 82:935-1016.

decades has been difficult and halting because of high capital costs and a lack of native engineering knowledge and experience in this method. In 1980 about 7 percent of underground production was from this method, and it is gradually increasing in use.

Comparison of Safety Performance

It is difficult to compare safety performance between nations because statistics are assembled on different bases. For example, the criterion in the United States for a disabling accident is failure of the employee to report for work at the next scheduled shift, whereas in the United Kingdom the worker must miss three days of work to be so classified. Thus, in the United States there would be injuries counted as disabling that would not be so classified in Great Britain.

Because of these discrepancies the only available basis for comparison is the number of fatalities. The number most frequently used for comparison is the fatality rate per 100 million employee-hours worked.

While the comparison in Table 4 indicates that the relative danger to the individual American coal miner working underground is greater than in any of the three European countries listed, it should be noted that over the period covered the danger is being reduced more rapidly in the United States than in the other countries.

It should also be noted that there is considerable difference between the productivity of the American miner and that of his European counterpart. When the cost in fatalities for producing a given amount of coal is studied, we have the different picture shown in Table 5.

This shows that the U.S. death toll per unit of coal produced is less than half that in the European Community, and that it was lower than in Great Britain until the 1975-77 period. It also shows that fatalities versus production in the United States increased slightly between the last two periods, while the fatality versus exposure rate decreased by 49 percent. This anomaly is due to a sharp reduction in productivity between the two periods.

Training in the United States

The Mine Safety and Health Act of 1977 requires that all new miners receive 32 hours of classroom training and

TABLE 4 Fatalities Versus Exposure in Several Coal Producing Countries

	Fatalities per 100 Million Employee-Hours Worked			
Period	United Kingdom	West Germany	France	United States
1950-64	32	65	36	106
1965-69	27	55	40	103
1970-74	20	42	48	88
1975-77	15	38	32	45

SOURCE: U.S. Bureau of Mines, as assembled by the National Coal Board of the United Kingdom.

TABLE 5 Fatalities Versus Production in Several Coal Producing Countries

	Fatalities per 100 Million Tons of Coal Mined		
Period	United Kingdom	European Community	United States
1950-64	119	235	54
1965-69	80	151	44
1970-74	54	105	38
1975-77	36	84	39

SOURCE: U.S. Bureau of Mines, as assembled by the National Coal Board of the United Kingdom.

8 hours of training at the job site, both devoted primarily to safety. Each company submits a training plan for approval to the state agency authorized by MSHA, or to MSHA in states without an approved agency. (In addition to the program for new miners, each operator must have plans for newly employed experienced miners, for training miners for new tasks, for annual refresher training, and for hazard training.)

The degree of compliance with these requirements ranges from the minimum to several times the minimum training required. Some mining companies have training centers with well-equipped classrooms and laboratories staffed by professional teachers who have worked in coal mines. Other companies have, in addition, small classrooms at each mine for short classes, such as refresher training. Several companies have underground laboratories where the miners can learn to operate each piece of equipment in a nonproduction situation.

Training in Other Countries

In many countries the miner has a much longer, more intensive, and more detailed training period than in the United States. In Great Britain the new miner has three years of training. The training includes 310 days of formal instruction and 100 days under continuous supervision. The new miner, after 10 days of "induction," spends a minimum of 100 days being trained before working underground, after which he is under the continuous observation of an experienced miner. When he starts to work he is given 150 days of special training for that job. He cannot work within 30 ft of the coal face until he has had a minimum of 120 days of training. When he completes three years of training he is ready to select his permanent job. To become a supervisor the worker must follow a somewhat different program, lasting six years, and pass an examination, after which he is certified as a deputy manager. There are a variety of programs leading to different staff and management positions, with refresher training at intervals of 2-1/2 to 5 years, depending on the job.

In West Germany a clear distinction is made between skilled miners (*Hauer*, *Knappe*) and unskilled workers. Unskilled workers always work under the supervision of skilled miners. They receive on-the-job training of several months. The training programs are developed by the mining company but must be approved by state authorities.

Skilled miners go through a three-year apprenticeship that includes on-the-job training and regular attendance at a state-supported vocational school. Normally the apprenticeship is begun after 10 years of public schooling, at about the age of 16. During the three-year apprenticeship the future mine electrician, mechanic, etc., is employed by the mining company under an apprenticeship contract that permits attendance at a state-supported vocational school several times during the week on company time (half days). After three years an examination must be passed to get the skilled miner's, electrician's, etc., certificate. Generally, the certificate is needed to get into any position at the lowest level of responsibility. Initial work is with experienced miners, electricians, etc.

For many years mining companies have maintained their own schools to provide additional education for the lowest level of management (Steiger), about equivalent to a foreman in the United States. This training is provided, at the company's expense, to ambitious young certified miners with a few years of experience. It involves two years of a preparatory mining school and three more years of attendance at a mining engineering school to obtain the Steiger diploma. This diploma is recognized by the state authorities and is required by companies for any position of responsibility (e.g., foreman, mine manager, etc.) in a mine. During the five-year schooling and training period the future Steiger will both work and attend school. Specialization in mining, electrical engineering, surveying, and coal preparation is possible. Mine safety training is stressed throughout this training period. To rise to the level of mine manager, superintendent, or higher, special one-year management courses must be attended. Again, the company pays for the schooling and provides time off the job.

Mining engineers (Diplom Ingenieur), on the other hand, will normally go through four years of grade school, nine years of high school, and four to five years of a mining engineering program at a university. Before being accepted by a university into its mining engineering program, future mining engineers must go through a one-year, tightly supervised training program that provides exposure to different mining technologies. Another 12 months of supervised practical training is required during their studies at the university.

Thus even the lowest level of management responsibility (Steiger) has at least 15 years of schooling, 5 of which are directly aimed at mining. A Steiger will normally move up to medium management levels (e.g., mine manager, mine superintendent). College-graduated mining engineers have 18 to 19 years of schooling and training behind them before they are employed as mining engineers; the last 5 to 6 years are fully devoted to education in mining engineering. Safety training is an integral part of the curriculum.

The result of such elaborate education is a highly professional attitude at all levels of mine management. Mine inspection agencies (Bergamt) that police the mining industry are staffed by graduates of universities or mining engineering schools. Quite often positions in these government regulatory agencies are a stepping stone for positions of high responsibility in industry.

The Polish miner may enter a basic mining school at age 14 or 15 for three years of classroom and job instruction, he may serve three years as an apprentice under a skilled miner, or he may attend a mining technical school for five years. Eighteen-year-olds who have completed secondary school may attend a mining technical school for two years, as may graduates of basic mining schools. Other 18-year-olds may go to a mine training center for at least 200 hours of instruction.

All Polish miners, including managers, must have 16 hours of retraining annually, concentrated on first aid and safety, with a qualifying examination. If the examination is not passed, the worker is demoted until he corrects the deficiency.

The Romanian worker has a minimum general education of eight years and two years of specialized training, which in mining communities covers mining in general and elementary technical subjects. The worker then usually spends two years in technical secondary education followed by 6 to 12 months as a trainee to become qualified as a miner. Those who do not take the last two years of education must pass an examination after 6 months as a trainee in order to qualify. To become a mechanic or other technician, an additional 18 months of training is required. Qualified miners may advance in the supervisory and engineering structure by a series of educational and production job periods. There is periodic retraining for all ranks.

In France the period of education for new workers is not specified but generally starts with two weeks in surface classrooms with an examination, followed by three or four months at a training face underground where coal is actually produced at a low rate by the students under close supervision. The miner then moves to a production face and training generally continues to a total of six months, with periodic retraining. To rise through each of the three classes of supervision requires successive periods of two to five years of practical experience while attending work improvement courses, with practical and oral examinations.

In Australia the required training is a minimum of five days, including classroom instruction and demonstrations, in suggested subjects before the worker begins production. After an examination the worker is under the supervision of a mine official until he achieves a degree of competency, then he works under an experienced miner for an unspecified period. Task training is required for any particular job undertaken. Special training is required for all types of technical, engineering, and supervisory positions. The mine operators have wide discretion in preparing a training program that will meet the requirements and be approved.

There are striking differences in training and certification requirements between the United States and the six foreign coal-producing nations examined above. First, U.S. mining law requires only 40 hours of instruction for the new miner; the other countries add to this. Second, federal safety laws have no requirement for certification of supervisors, in sharp contrast to the certification only after extensive education and experience in all of the foreign countries except Australia.

The training requirements for new miners, according to the study, were lowest in Australia. The requirements range upward to those of Great Britain, where 100 days of classroom and closely supervised practical instruction precede any work; furthermore, the new worker then receives 150 days of special training in selected skills, becoming certified as a miner only after three years of training.

In the area of the qualification and certification of supervisors, Australia again has the least stringent requirements. There a mine manager (equivalent to a mine foreman) is required to have five years of experience or three years of experience and either an engineering degree or two years of training at a mining school. The other five countries vary widely in their requirements, with Great Britain apparently the most severe in requiring four years of experience as a certified miner and 280 hours of technical education to take the examination for deputy, the lowest step on the management ladder; a degree in mining engineering offsets a significant portion of the total experience required.

Training and Certification Requirements of States

Of the 15 states that produced coal from underground mines in 1979, 10 have no training or experience requirements for a new miner beyond the 40 hours of training required by federal law. Kentucky requires 90 working days of experience within sight and sound of a certified miner, followed by an examination to become certified. Indiana requires a six-month apprenticeship with an experienced miner before the miner can work alone. Pennsylvania requires one year of apprenticeship under close supervision, followed by an oral, practical examination. Illinois requires a one- to two-year (maximum) apprenticeship followed by an oral and written examination, with completion of training in first aid and mine rescue; holders of an associate degree in coal mine technology or a bachelor's degree in engineering can waive six months of experience. West Virginia requires 80 hours of instruction followed by an examination to qualify as an apprentice; the new employee then works six to eight months (maximum) within calling distance of a foreman, assistant foreman, or designated experienced miner. Six states certify certain workers such as shot firers and electricians. All but Maryland and Iowa certify firebosses or mine examiners.

With respect to qualification and certification of supervisors, Maryland has no provision for certification and mine foremen have not been certified by Iowa since 1973, when the state closed its department of mines to avoid duplicating the work of the federal government. In the other 13 states with underground mines, foremen (and usually assistant foremen) are examined and certified after two years of general underground work or one year of specialized experience (six months as a certified shot firer followed by six months as a certified mine examiner). In 10 states some credit is given for education, from one year to three, depending on the state and the degree earned.

The mine superintendent is the person who directs the mine foreman's activities. He usually has the final authority at the mine site. Only Utah and Kentucky specify his qualifications: In those states he must have foreman's certification.

HISTORY OF MINE SAFETY LEGISLATION

Background

During the nineteenth and early twentieth centuries mine safety was almost exclusively the domain of individual states. Courts routinely adhered to the notion that mining, as such, was not interstate commerce. From this premise flowed the legal conclusion that Congress lacked the constitutional authority to enact legislation regulating mining in general or underground coal mine safety in particular. These earlier constraints were not relaxed until the late 1930s, when the U.S. Supreme Court began to render decisions that significantly broadened the powers of Congress to legislate under the Commerce Clause of the Constitution (Nowak et al., 1978; Tribe, 1978).

Accordingly, for all practical purposes the early history of mine safety legislation in this country is the history of state legislation.

State Law and Legislation

Common Law Duty

Even in the absence of specific statutes, employers were under a general legal duty to exercise reasonable diligence in providing safe working conditions. Many state courts judicially recognized the extrahazardous nature of underground mining. Some went so far as to indicate that mine operators had a somewhat higher duty of care (i.e., a duty to take more precautions) because of the dangerous nature of the work.

> A greater degree of care is required of the master who places his servant at work in a coal mine beneath overhanging masses of rock which are liable to fall at any moment. . . . [T]he greater the danger a prudent man would apprehend, the higher the degree of care and diligence of the master in the protection of the servant (Ashland Coal Co. v. Wallace, 1897).

Unfortunately, these judicially created "common law" doctrines only provided compensation in money damages after an injury or fatality had already occurred. At best, this duty of reasonable care provided merely an indirect incentive to greater workplace safety. At worst, it was illusory, because other common law doctrines, such as contributory negligence, assumption of risk, and the fellow servant rule, often combined with the rather nebulous standard of "reasonable care" to defeat even the modest recovery of a few thousand dollars for a lost life or a serious injury.

In order to impose specific, enforceable safety precautions designed to prevent hazardous conditions before injuries occurred, legislation would be required.

State Statutes

Pennsylvania was a pioneer in enacting mine safety legislation. Its act of March 3, 1870, which was modeled after an English mine safety statute, provided in some detail for safety conditions, but only in anthracite mines. For instance, mine operators were required to make accurate maps or plans of workings and update them periodically. Two shafts or outlets were required for each existing mine or working where more than 20 persons were employed. A minimum ventilation standard was established: at least 3,300 cu ft/min for every 50 men at work in the mine. A specific requirement was made for the employment of a competent "mine boss," whose duties included the monitoring of ventilation, airways, travelways, pumps, timbering, roof conditions, gas accumulation, "and all things connected with and appertaining to the safety of the men at work in the mine." Among other safety conditions explicitly covered by the act were man hoists and their operation, communications with the surface, and safety lamps.

The Pennsylvania act provided for the appointment of qualified mine inspectors. In addition to a duty to inspect for compliance with statutory mandates, and for "all matters . . . relating to the safety of the persons employed [in a mine]," the inspectors were authorized to investigate any accidents that were not the subject of a coroner's inquest. Inspectors had an explicit right of entry to mines and were required to compile annual reports.

Enforcement of the Pennsylvania act was through a combination of injunctions, criminal sanctions, and private damage actions. Courts were authorized to enjoin violations of the act. Violations of most provisions could result in fines and incarceration (a maximum of $500 and one year). Moreover, individual employees were also subject to fines and imprisonment for certain unsafe actions (e.g., intentional damage to safety lamps, carrying lighted pipes or matches, or any act endangering the lives or health of others). Finally, persons injured by a violation of the act or by a willful failure of an operator to comply with any provision of the act were given an explicit right of action for any resultant damages. As with many other pieces of state, and later federal, legislation, the Pennsylvania statute seems to have been triggered by prior mining disasters.

Other state enactments soon followed. By 1894 a publisher of works aimed at the practicing attorney deemed the topic to be important enough to warrant a brief survey of cases that had arisen under state mine safety statutes (Lawyers Reports Annotated, 1894). Very few of the cases seem to have arisen out of direct enforcement actions taken by state authorities; the bulk of the legal actions included in this survey involved individual suits for damages occasioned by injuries or fatalities sustained in mining accidents. The survey indicated that at least five states--Pennsylvania, Ohio, Illinois, Missouri, and Tennessee--had enacted mine safety legislation of some substance. There were at least two more states that had underground mine safety legislation by 1894--West Virginia and New York.

The subjects dealt with by state legislation tended to fall into certain broad, general categories: roof support, ventilation, escapeways, man hoists and cages, and the competence of foremen. In almost all states a statutory duty was imposed on mine operators to supply sufficient timbers for roof support. However, the statutes sometimes did not impose an affirmative duty on the mine operator to prop the roof adequately throughout the entire mine; the duty was often one of simply supplying enough timbers for the miners to do it themselves. Ventilation, as might be expected, was a common subject of mine safety legislation. Most statutes prescribed a certain minimum air flow rate; others prescribed in more or less detail the various equipment required. Other safety measures commonly prescribed by statute involved man hoists, surface communication, signals, and some form of requirement for minimal competence of mine foremen, often to be certified by a board of state examiners.

Most state statutes provided for inspection by a state mine inspector. Enforcement measures and sanctions ordinarily included misdemeanor-level fines or penalties and possible jail sentences. Some states empowered the courts to issue injunctions against violations of the statutes. In many states there were specific provisions for individual damage suits where injuries or fatalities had occurred because of violation of the statutes.

The enactment of state legislation was by no means a systematic or smooth undertaking (Graebner, 1976). Even within individual states the dates of various statutes imply something of a piecemeal, trial-and-error approach.

For example, Pennsylvania enacted statutes in 1870, 1871, and 1885. The statutes of Illinois were enacted in 1872, 1877, 1879, 1887, and 1891. The effectiveness of these state efforts is probably a matter for conjecture. All that can conclusively be said is that, as of 1902, the reported cases seldom dealt with direct enforcement activities. Most of the litigation arose out of damage actions brought by private parties.

By the middle of the twentieth century the effectiveness of state mine safety laws, the degree of their enforcement, and the degree of mine operator compliance all had become a subject of some dispute. In 1952 a U.S. Senate committee report (Senate Report No. 1223, 1952) asserted:

> . . . 29 coal-mining states have enacted an infinite and confusing variety of laws affecting the safety of coal miners. While some States have had adequate enforcement of these State laws, in others they have often been carried out in an indifferent and haphazard manner. . . .
>
> Testimony before the subcommittee revealed that State inspection of Orient No. 2 Mine . . . was wholly inadequate and that violations of State laws were not ordered corrected even after being called to the attention of State authorities by the United States Bureau of Mines. . . . The inevitable result of this confusion and subdivided responsibility has been the frequent recurrence of accidents, fatalities, and major disasters.

Whether warranted or not, such criticism was a sign of growing momentum toward federal legislation.

Federal Legislation

Direct federal regulation of underground coal mine safety became legally possible only after the barriers of earlier judicial precedents were lowered by the Supreme Court in the late 1930s. Prior to this there had been a few gestures in the direction of some federal contribution to mine safety, primarily the creation of the U.S. Bureau of Mines. In some instances, later federal legislation was limited to conditions with the potential for disaster. Only in 1969 was federal legislation dealing comprehensively with coal mine safety enacted.

The first venture by Congress into general matters of mine safety occurred in 1910. In that year, following a series of mine disasters around the turn of the century, Congress established the U.S. Bureau of Mines as part of the U.S. Department of the Interior. In keeping with then-prevailing constitutional doctrines, the Bureau was strictly an information-gathering agency, lacking the power even to require mine operators to allow its agents to enter mine property. Not until 1941 was the Bureau given the authority to enter and inspect underground coal mines. Yet it still had no authority to establish mandatory safety standards or to enforce compliance with safety measures in any way. The Bureau was limited to obtaining and publishing information.

Underground coal mine disasters continued. Following the West Frankfort, Illinois, incident, in which 119 miners were killed, Public Law 552, Ch. 877, 66 Stat. 592, was enacted in 1952. The 1952 act was aimed at preventing major disasters. Although somewhat limited in scope, the 1952 act represented a landmark in federal underground coal safety legislation. Bureau inspectors could issue orders withdrawing miners from all portions of a mine where there was an imminent danger of explosion, fire, inundation, or a man-trip or man-hoist accident. In addition, statutory standards for conditions with disaster potential were established under Section 209 of the act. Basic minimum requirements, albeit sometimes phrased in general terms (e.g., adequately supported, dangerous quantities), were established for such matters as roof support, ventilation, rock dusting, mining near abandoned workings, smoking, hoisting, and blasting. For violations of Section 209, inspectors issued notices of violation to the operator requiring correction of the violation. If the violation were not corrected, an order would be issued to withdraw miners from the area of the mine affected by the violation.

The 1952 act, however, excluded from all mandatory provisions any mine employing 15 or fewer miners underground. Conceptually, there was also the problem that the sanctions and enforcement scheme were predicated upon correcting imminent dangers and other hazards <u>after</u> an inspector discovered them, rather than preventing unsafe conditions in the first place. Virtually the sole remedy available to the Bureau was the withdrawal order. The same hazard with disaster potential could be encountered again and again in the same mine, with the remedy being limited to requiring correction of the condition.

In 1966, amendments to the 1952 act eliminated the exemption for mines with fewer than 15 miners working underground and authorized federal inspectors to issue withdrawal orders to deal with especially serious repeated violations (i.e., those which, while not an imminent danger, were unwarrantable and could significantly and substantially contribute to explosions, fires, floods, or man-trip or man-hoist accidents).

Conditions not constituting imminent dangers, or not covered by Section 209 of the 1952 act as amended, were left entirely to state law or the Bureau of Mines Advisory Coal Mine Safety Code. During the period 1960-68, violations of the advisory code numbered 1.3 million, of which 231,000 were corrected voluntarily by operators. In contrast, violations of state law and federal violations for which correction could be required by law numbered 91,940, with some 78,000 being abated promptly and the remainder being abated after issuance of a notice of violation.

The 1969 Mine Safety and Health Act (the Coal Act) was passed on the heels of the 1968 Farmington, West Virginia, disaster, in which 78 miners were killed. The 1969 act was the first comprehensive mandatory federal system covering all coal mines. Inspection and enforcement provisions were set out in Title I of the act, and under Titles II and III statutory and mandatory standards were established. These statutory "interim" standards were to be gradually replaced by improved standards administratively promulgated by the Department of the Interior. Under Title I, inspection of each underground coal mine, in its entirety, at least four times per year was required. Enforcement tools given to the Secretary of the Interior included the authority to issue withdrawal orders for (1) imminent dangers, (2) failures to correct violations, and (3) unwarrantable violations that could significantly and substantially contribute to a hazard. In addition, to provide an incentive to prevent hazardous conditions from developing in the first instance, mandatory civil money penalties for all violations were provided, as were criminal sanctions for willful violations.

From 1970 to 1977 several more mine disasters again generated congressional interest in strengthening and broadening the Coal Act. For instance, 91 miners died in the Sunshine Silver mine in Idaho, giving impetus to bringing other kinds of mining under legislation similar to the 1969 Coal Act. In West Virginia in 1972 a coal mine impoundment dam at Buffalo Creek burst, flooding the valley and killing 125 people. In 1976 two explosions at a single mine (in Scotia, Kentucky) killed 23 miners and three federal inspectors. In 1977 nine miners died when underground workings of a mine at Wilkes-Barre, Pennsylvania, were flooded.

In 1977 new legislation transferred the responsibility for federal mine safety and health regulation to the Department of Labor and established the Mine Safety and Health Administration in the department. The 1969 act was expanded to include metal and nonmetal mining (previously covered by a 1965 act), and several amendments were added to strengthen enforcement and rule-making authority. A special statutory provision was made for mandatory training regulations to be promulgated by the Secretary of Labor. Despite various changes in nomenclature, procedure, and enforcement provisions, most of the underlying concepts of the 1969 Coal Act were carried over into the 1977 Mine Safety and Health Act.

PRESENT FEDERAL LEGISLATION

Briefly summarized, the present federal legislation can be described as follows. The basic enforcement system consists of (1) administratively promulgated regulations, (2) inspection of mines by federal inspectors to determine compliance with those regulations, and (3) remedial actions in the form of withdrawal orders and sanctions consisting of civil and criminal penalties for noncompliance. In addition to the law's enforcement aspects, the Secretary of Labor is directed by Section 502(b) of the 1977 Mine Safety and Health Act to provide technical assistance to mine operators to help them not only comply with the act but also further improve safety conditions and practices.

Promulgation of Regulations (Standards)

Regulations specifically aimed at safety or health hazards are termed mine safety or health standards under the act. Insofar as the substance and content of the standards are concerned, MSHA generally has wide latitude. The 1977 act allows the promulgation of any safety or health standard that bears a rational relationship to the hazard dealt with by the standard. The main substantive restraint on the content of any new or revised standard is that it shall not lessen the protection afforded miners under prior standards.

The procedures for promulgation of a standard are more detailed. Generally, once MSHA determines the need for a new or revised standard, a proposed standard is developed (often with the aid of an advisory committee) and published. Interested parties are given an opportunity to furnish written comments on the proposal and to request a public hearing. In most cases MSHA holds public hearings. After the period for public comment and hearings has ended, MSHA evaluates the proposed standard in light of the public input. If the standard is then promulgated, interested parties have 60 days to file a direct appeal or challenge to the standard in a U.S. Court of Appeals.

In theory at least, the standard-setting procedures under the act provide the machinery for an ongoing evaluation of safety and health needs in underground coal mines, for a timely response to technological developments and other changes in the industry, and for continuing improvement in required safety equipment and practices in underground mining.

Inspection and Enforcement

MSHA is required to inspect each underground coal mine in its entirety at least four times each year. Each surface coal mine must be inspected in its entirety at least twice each year.

Enforcement of the act and standards is achieved through a combination of citations, withdrawal orders, and penalty sanctions. If an inspector finds a violation of a standard, a citation is issued describing the violation and giving a period of time in which to correct the condition. Under certain defined circumstances an inspector may issue a withdrawal order--an order that all persons in the area of a violation or a hazard withdraw from the area, except those persons needed to correct the violation or hazard. Withdrawal orders may be issued in cases of (1) imminent danger (whether or not there is a specific violation of a standard), (2) failure to correct a violation in the time allowed by the citation, (3) unwarrantable violations, and (4) all "significant and substantial" violations occurring after MSHA has found that a "pattern" of violations exists in the mine. For any violation of a standard a proposed penalty will be issued by MSHA. Criminal sanctions are possible in cases of willful violation.

Citations, proposed penalties, and withdrawal orders may be challenged before the Federal Mine Safety and

Health Review Commission, an independent quasi-judicial agency established by the 1977 act. An administrative law judge employed by the commission will conduct a hearing and render a decision that is reviewable by the commission. Decisions by the commission can be further reviewed by U.S. Courts of Appeals.

Miscellaneous Provisions: Miner Participation, State Law, Training

Participation by miners in the inspection and enforcement system is an integral part of the 1977 act. Miners' representatives are entitled to accompany an inspector during the inspection, with at least one such representative being entitled to do so with pay. Miners or their representatives may obtain an inspection by MSHA when there are reasonable grounds to believe that a violation of the act or a standard exists. Various other participatory rights are given to miners and their representatives under the 1977 act--for example, a right to participate in hearings before the commission and its administrative law judges in cases arising out of operator challenges to a citation, penalty, or withdrawal order. Moreover, a stringent antireprisal provision is included in the act, forbidding any discharge or any form of discrimination against miners because of their exercise of rights under the act.

The 1977 act, like its predecessors, does not generally preempt state laws or regulations. Only those state laws or regulations that are "in conflict with" the act or federal standards are superseded [Section 506(a)]. Moreover, Section 503 of the 1977 act provides for federal grants to the states to assist them in developing and enforcing their laws.

Finally, an important innovation in the 1977 act is the provision imposing certain minimum requirements for miner safety and health training. Under Section 115 of the act, each mine operator must have a health and safety training program approved by MSHA (see "Training in the United States" earlier in this chapter).

The basic concept is that each mine operator will provide, directly or indirectly, a training program that meets certain basic criteria as to time and subject matter. The training program must be approved by MSHA and conducted in accordance with MSHA regulations. Within the statute and the regulations there is considerable latitude given to mine operators to develop and carry out training programs tailored to the individual mine. There is no legal barrier to mine operators who wish to do more than is required, and also no legal barrier to MSHA's requiring more than the statutory minima by issuing additional regulations.

THE U.S. COAL INDUSTRY: A DESCRIPTIVE SUMMARY

The Economic Setting

The 1970s were a decade of modest economic growth. Although the gross national product (GNP) increased from $993 billion in 1970 to more than $2.6 trillion in 1980, the increase of 165 percent primarily reflected inflation. When the volume of goods and services is expressed in constant (1972) dollars, the increase from $1.1 trillion to slightly less than $1.5 trillion comes to only 36 percent.

The coal industry contributes a minuscule share of this aggregate measure of economic activity. In 1970, for instance, the total value of coal produced in the United States in current dollars was $3.8 billion, only 0.38 percent of the GNP. By 1980 this share had more than doubled to 0.82 percent.

The relative insignificance of coal in the most widely used measure of aggregate economic activity might seem surprising, since coal is a basic input. Without coal a substantial share of the nation's industrial activity would grind to a halt, and many utilities would be forced to close, depriving households, as well as commercial and industrial establishments, of electricity. But the reason for coal's relatively small share in GNP is clear. The gross national product has become increasingly weighted by the service and governmental sectors, which means that the share accounted for by the goods-producing sector has had to decline.

A more meaningful indicator of the relative importance of coal in the national economy is its relation to the value of manufacturing sales, with both expressed in current dollars. In 1970 the value of U.S. coal production amounted to 7.2 percent of manufacturing sales. By 1980 this indicator had climbed to 14.4 percent, or twice the earlier percentage.

In spite of the fairly rapid expansion of coal production during the 1970s, coal provided a declining share of U.S. gross energy consumption. In 1960 this share amounted to 23 percent. By 1980 coal's share had dropped to 17.8 percent.

Recent Trends in Coal

Figures 8 and 9 show what happened to coal production, employment, and productivity between 1970 and 1980. Production increased by 29 percent, somewhat slower than real GNP. But the value of coal sales rose from $3.8 billion to $21.6 billion, a whopping gain of 468 percent. The volume of underground coal production dropped slightly during the 1970s, but the sales value of underground coal increased 320 percent.

There was a 75 percent increase in total coal-mining employment during the 1970s. In absolute terms, slightly more than half of the gain was in underground mines. Because of the much higher base from which it is measured, the relative increase (55 percent) for underground mining was smaller than that for the coal industry as a whole.

Productivity (measured as output per employee-day) dropped substantially between 1970 and 1980. Across the industry there was a decline of 20 percent. The drop in underground mines was larger than that in surface mines, 35 percent in the former, 24 percent in the latter. This change in the coal industry is particularly significant since much of the decline in productivity has been attributed by the operators to enactment of the Mine Health and Safety Act of 1969 (FlorJancic, 1980).

A major change in the coal industry since 1960 has been a substantial decline in the number of mines in operation and a corresponding increase in the relative size of those that continue to operate. Figure 10 shows the decline from 1960, when there were 7,865 mines in the country, to 1979, when this number had decreased to 4,243. Much of the decline was in underground mining. In 1960 underground mines accounted for more than 76 percent of the total. This share had dropped to roughly 45 percent by 1979. There was a sharp, but brief, increase in the number of mines operating after oil (and coal) prices spurted upward in 1973. Gradually the long-term trend reasserted itself, however, and the number of mines began to drop again after 1976.

Table 6 provides information about the characteristics of mining companies, as opposed to individual mines. In 1960 firms with one to nine employees operated 72 percent of all mines, accounting for 16 percent of the industry's

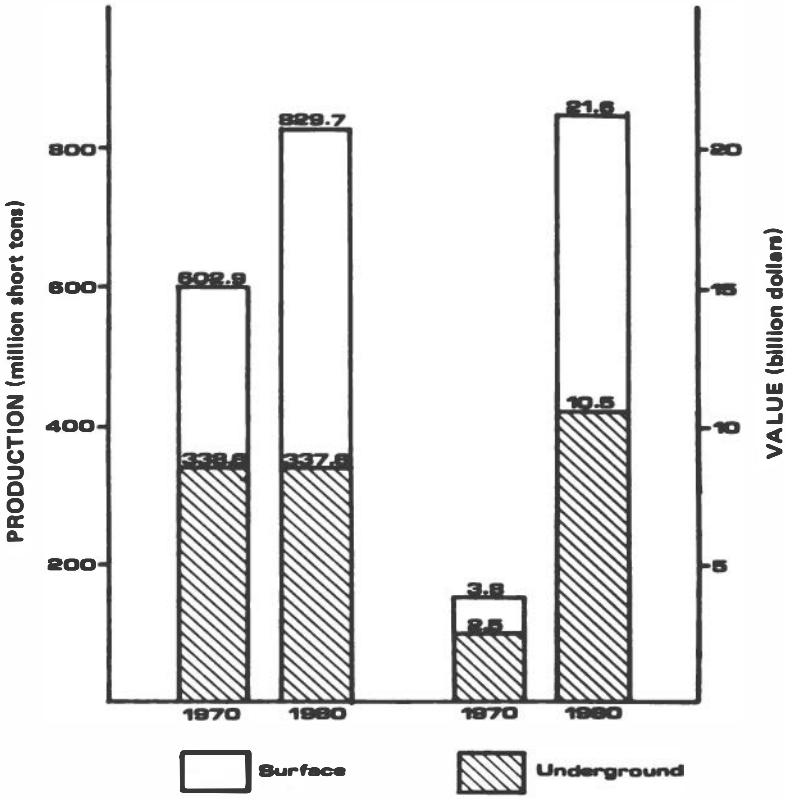

FIGURE 8 Coal production, quantity, and value in 1970 and 1980. Sources: Production--Bureau of Mines (1975); personal communication, Leonard Westerstrom, Department of Energy, July 15, 1981, preliminary figures. Value--Bureau of Mines (1970); personal communication, Leonard Westerstrom.

employment. By 1978 these small companies operated only 36 percent of all mines and accounted for about 5 percent of total employment.

The largest increase came in the intermediate category of firms employing 10 to 149 workers. In 1960 medium-sized firms operated about 26 percent of all mines and accounted for about 40 percent of all employment. In 1978, however, their share of mines had increased to 58 percent and they accounted for almost 48 percent of the total employment. The share of the largest companies,

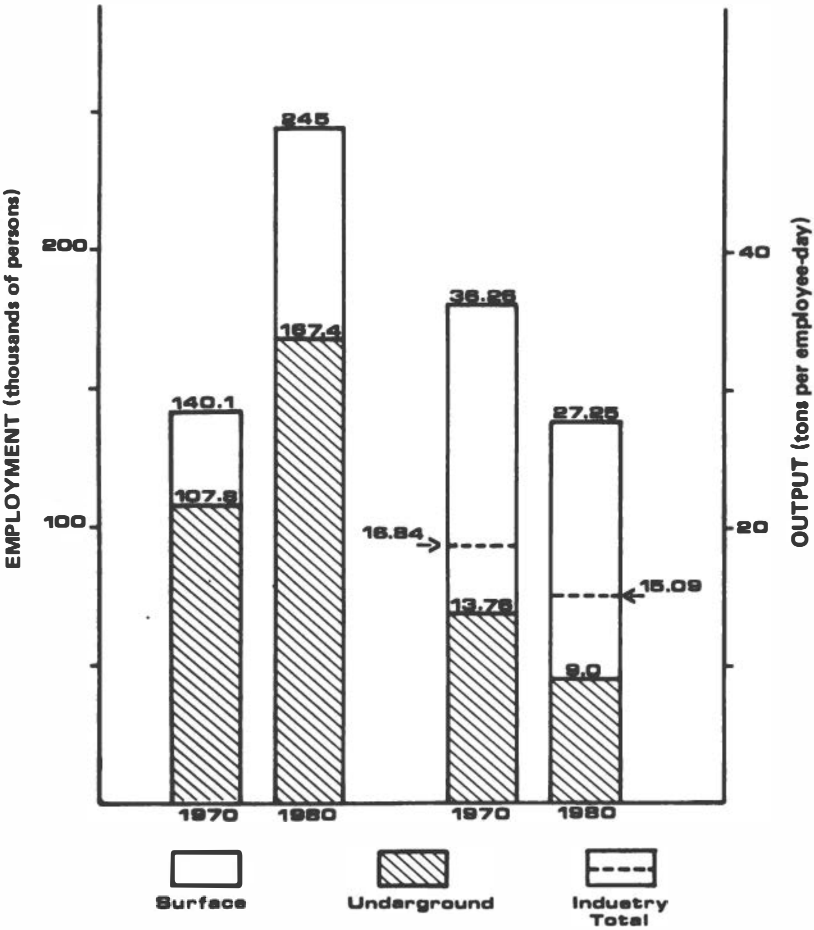

FIGURE 9 Coal employment and productivity in 1970 and 1980. Sources: Employment--Bureau of Mines (1975); personal communication, Leonard Westerstrom, Department of Energy, preliminary figures. Productivity--Department of Energy (1979); personal communication, Leonard Westerstrom.

with 150 or more employees, increased from 2.6 percent of all mines (and 44 percent of employment) to 5.8 percent of all mines (and 47 percent of employment) during this period.

Shifts in production were somewhat smaller than those in employment. There was a sharp drop in the percentage

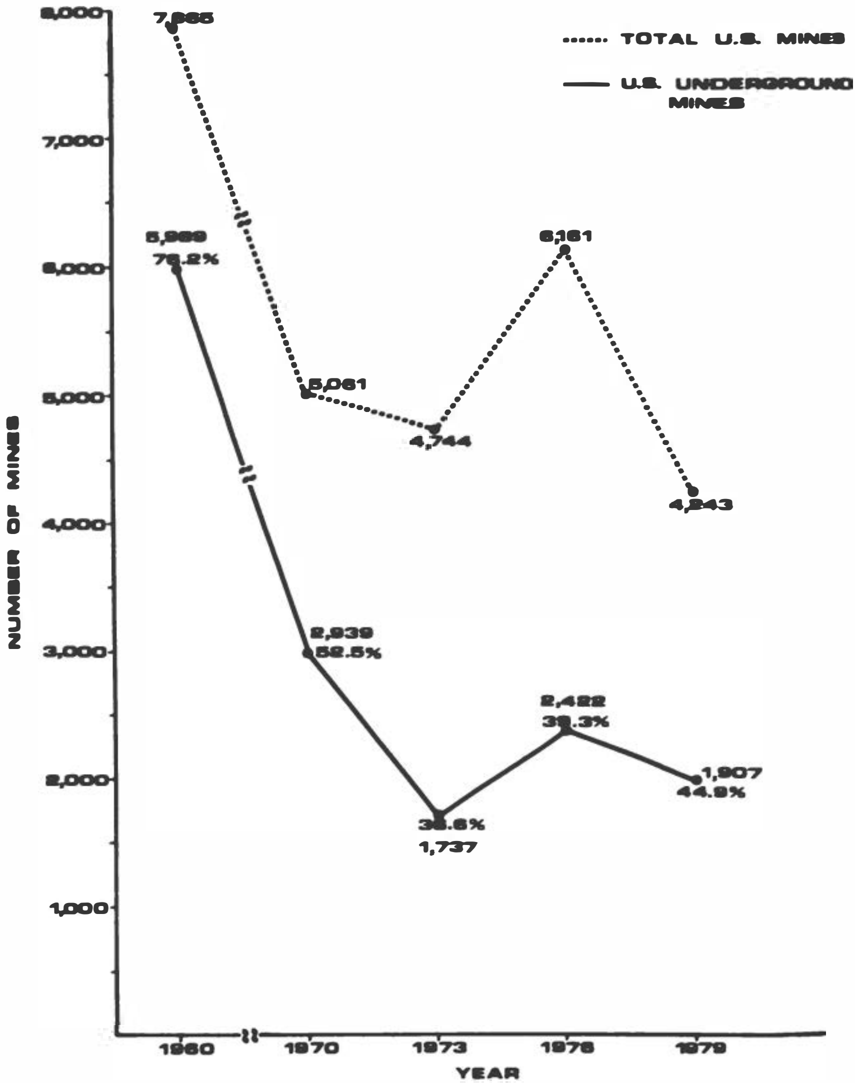

FIGURE 10 Active bituminous coal and lignite mines in the United States, 1960-79. Sources: Bureau of Mines (1961, 1972, 1975, 1978); Department of Energy (1981). Note: 1979 figures do not include mines with less than 10,000 tons production.

TABLE 6 Distribution of Employment, Production, and Assets in Coal Mining by Size of Firm, Selected Years, 1960-78

Size Class	Employment 1960 Percent of Employment	Employment 1960 Percent of Mines	Employment 1978 Percent of Employment	Employment 1978 Percent of Mines
All mines	100.0	100.0	100.0	100.0
150 employees and over	43.8	2.6	47.0	5.8
10 to 149 employees	39.9	25.7	47.9	58.3
1 to 9 employees	16.3	71.7	5.1	35.9

Size Class	Production 1960 Percent of Total Tonnage	Production 1960 Percent of Mines	Production 1978 Percent of Total Tonnage	Production 1978 Percent of Mines
All mines	100.0	100.0	100.0	100.0
500,000 tons or more	49.3	2.6	50.0	3.8
100,000 to 499,999 tons	28.4	6.6	28.8	14.6
10,000 to 99,999 tons	17.4	31.8	20.0	56.3
Less than 10,000 tons	4.9	59.1	1.2	25.3

Size Class	Assets* 1960 Percent of Industry Assets	Assets* 1960 Percent of Corporations Filing Returns	Assets* 1975 Percent of Industry Assets	Assets* 1975 Percent of Corporations Filing Returns
All corporations filing returns	100.0	100.0	100.0	100.0
$25,000,000 and above	55.2	0.9	68.7	1.9
$5,000,000 to $24,999,999	24.9	2.6	15.6	5.7
Under $5,000,000	20.0	96.4	15.7	92.4

NOTE: Detail may not add to totals because of rounding.
*1975 data include anthracite.

SOURCE: Bureau of Labor Statistics (1981), p. 5.

of production by mines producing 10,000 tons or less annually. At the other end there was only a slight increase in the output of mines producing a half million tons or more annually. Mines whose output ranged between 10,000 and 99,999 tons increased their production moderately, but production in the next category, which includes mines producing 100,000 to 499,999 tons, changed little.

In 1960, 96 percent of the mining corporations filing returns reported assets of less than $5 million, accounting for 20 percent of the industry's assets. Fewer than one percent of the corporations reported assets of $25 million or more. Collectively, however, they accounted for more than 55 percent of the industry's assets. By 1975 the concentration of assets had increased substantially. Ninety-two percent of the corporations filing returns still reported $5 million or less, but they now accounted for only 15.7 percent of the total. Meanwhile, the percentage of companies reporting $25 million or more had increased to 1.9 percent, and the larger firms accounted for almost 69 percent of the industry total.

Long-Term Trends

In the past the American coal industry was highly unstable. It approximated the perfectly competitive markets discussed in introductory economics textbooks. A combination of aggressive price competition and weak unions--which permitted continuous downward pressure on wages--led to a series of "boom and bust" cycles. One of these complete cycles is illustrated by Figure 11, which shows total coal production from 1925 to 1975. The chart also shows the growing importance of surface mining after 1935, as well as the technological transformation of the industry from hand to mechanical loading.

The production and employment cycles of the past are not likely to be repeated in the future. World energy markets changed dramatically during the 1970s as the result of major increases in world oil prices in 1974 and 1978. A large number of coal forecasts have been made by federal and private agencies, and none shows a downturn in projected coal production. A consensus forecast would show total coal production passing the billion-tons-per-year mark sometime before 1990. The old days of boom and bust appear to have been replaced by a period of relatively slow but steady growth in coal production, at least for the remainder of this century.

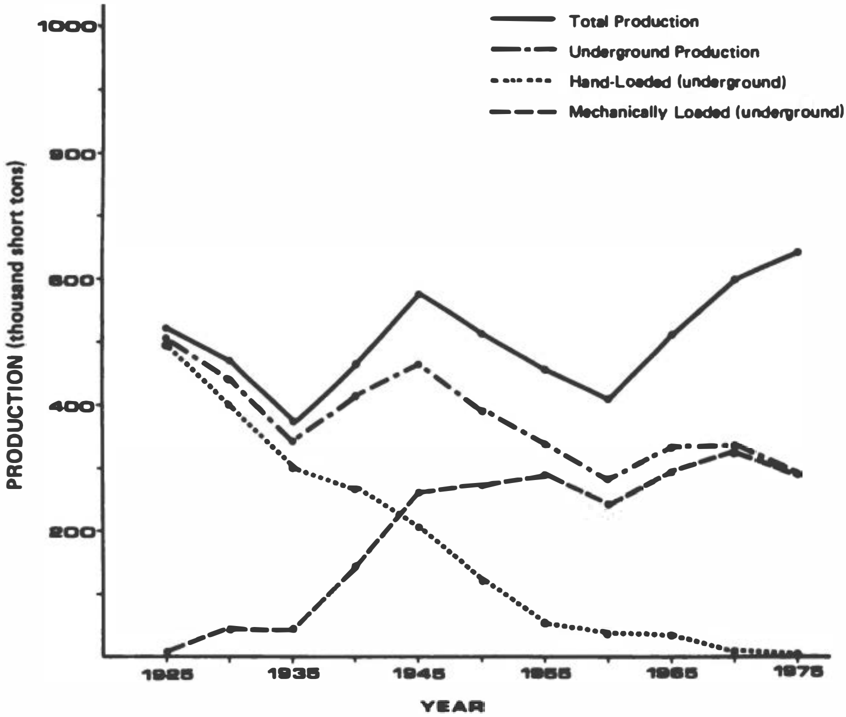

FIGURE 11 Production and production methods in underground bituminous coal and lignite mines in the United States, 1925-75. Source: Bureau of Mines (1967, 1972, 1977).

Geographical Distribution

The underground coal industry is highly concentrated in the Midwest (Illinois and western Kentucky) and in Appalachia (Pennsylvania, Ohio, Virginia, West Virginia, eastern Kentucky, and Alabama). As noted earlier, surface mines accounted for the entire increase in coal production between 1970 and 1980. Figure 10 showed that the number of underground mines decreased markedly between 1960 and 1979. There also have been pronounced changes in the size of underground mines, but the pattern among states is not a uniform one.

Production in the largest-size category increased in Illinois and Kentucky between 1967 and 1979. The output of mines in Pennsylvania producing 500,000 tons or more annually underwent a pronounced drop; however, there was a slight increase in the next size category in Pennsylvania (200,000 to 499,000 tons). The Virginia pattern followed that of Pennsylvania in the first two categories, although the changes were not as pronounced. West Virginia lost ground in both of the larger categories but registered an increase in the third size group (mines producing between 50,000 and 199,000 tons per year). Virginia and Kentucky also registered large increases in the third category.

The long-term trend in many industries in the United States has been toward fewer but larger establishments. The conventional explanation attributes this to economies of scale. Changes in underground mining in Illinois and Kentucky are consistent with the conventional view. But the shifts in Pennsylvania, Virginia, and West Virginia have been in the opposite direction.

It would be misleading to suggest that the reasoning applied to manufacturing economies of scale necessarily applies to underground coal mining. In addition to the customary economic and technological variables influencing size, coal mines are affected by geological considerations. Regional variations in the relationship between mine size and output are no doubt a result of all three sets of causes.

THE AMERICAN COAL MINER

There were 245,000 working coal miners in 1980, 151,000 of them employed underground. Mechanization and a coal recession decreased the underground workforce from 420,000 in 1940 to 109,000 in 1965. After 1965, coal production began to increase and a demand for new miners arose (see Table 7).

Although coal production has increased in the West, much of it is surface mining. More than 90 percent of all underground coal miners still live east of the Mississippi, a majority of these in the Appalachian mountains (see Table 8).

The underground coal miner today is much younger than the miner 20 years ago. In 1961 only 2.9 percent of bituminous coal miners were under 30 years of age. By 1971 this group made up 20 percent of the workforce, and by 1979, 41 percent were under 30.

For two decades after World War II the coal industry employed few new workers. This resulted in a rapidly

TABLE 7 Labor Force in Coal Mining

Year	Persons Working Daily in U.S. Coal Industry
1950	483,000
1955	260,000
1960	190,000
1965	149,000
1970	144,000
1975	218,000
1980	245,000

NOTE: This table pertains to all workers in the industry, including those working underground.

SOURCE: President's Commission on Coal (1980).

aging workforce. The median age of the workforce in 1964 was 48. By 1967 most miners were in their late 40s or 50s. As new miners were employed after 1965, a sharply divided workforce developed in terms of age. A large group was nearing retirement, while the new miners were in their 20s. Today, fewer and fewer older miners remain, and only a sprinkling of mid-career workers are available; young and relatively inexperienced miners increasingly dominate the labor force. By 1975 the median age had dropped to 34 and is probably close to that today.

The makeup of the supervisory workforce follows the same pattern. As superintendents and foremen retire, they are replaced by much younger persons. This varies considerably by mine and region. The median age in the newer western operations is around 27, and in some new mines in the East all workers including superintendents are under 35. Many mine superintendents today are in their early 30s. This generation gap affected work relations.

A survey of 25,000 new workers hired at United Mine Workers mines in 1975 found that about 76 percent of the new miners had no prior experience in the industry. Coal companies were no longer able to employ from a substantial

TABLE 8 Geographical Distribution of Active Coal Miners (January-June 1979)

Region	Percentage
Northern Appalachia	30
Central-Southern Appalachia	40
Midwest U.S. and Alabama	22
West of Mississippi River	8

pool of experienced miners. This was a complete reversal of the situation 10 years before and produced a great need to develop training programs for new miners (United Mine Workers of America, 1976).

Today's young miner is better educated than the miner 20 years ago. In the 1960s the average education of miners was fourth through seventh grade; miners with high school or college educations were rare. Many miners today complete high school and receive education in mining at a technical school or community college. In 1975 about a third of the miners had some education past the high school level. The President's Commission on Coal (1980) estimated that three fourths of entering miners have at least a high school education.

Miners are also a different group in other ways. Since 1973, women have been entering the workforce. The Coal Employment Project (1979) estimates that more than 3,000 women miners have been hired as a result of pressure from women's advocacy groups and changes in federal laws regarding sex discrimination. An estimated 10,000 miners are Black, Hispanic, or Indian.

Since 1974 coal miners' wages have risen faster than those of the general labor force, and they are among the nation's highest-paid workers (see Figure 12). In the past, and to a lesser extent today, the instability of the industry, marked by frequent layoffs, work stoppages, and contract strikes, made it difficult for miners to count on a continuing or predictable yearly wage. In 1978, 33 percent were not working for some period, and in 1980-81 a number of layoff periods occurred. When employment is stable, miners receive annual wages of $15,000 to $20,000 (in the 1975-79 period). The President's Commission on

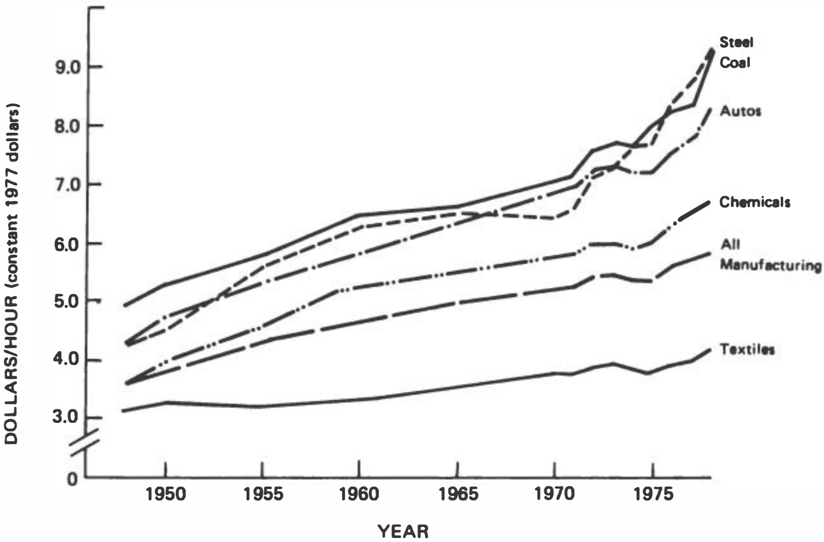

FIGURE 12 Hourly earnings (in constant 1977 dollars) for the bituminous coal industry and other major industries, 1948-78. Source: President's Commission on Coal (1980). Note: Earnings are hourly averages for the year, except for the 1978 figures, which are hourly earnings for October 1978. GNP implicit price deflators are used in computing the 1977 dollar wages.

Coal reported from a survey of 1,281 miners in 1980 an average income of $19,442.

The image of the coal miner as a dirty, ignorant, substandard human with a strong back, a weak mind, and a poor ill-fed family living in a shack on the side of a mountain dies slowly. Today's coal miner, with stable employment, seeks to maintain a middle-class life style. He views himself more and more as a skilled technician, and the miner and his family are more integrated into the general community. The isolated, company-controlled coal camps of the early mining days have disappeared. Those that remain have changed to independent towns with former company houses now owned by working or retired miners. But the increase in the labor force has produced a present need for new housing. In many areas of the coalfields, few homes have been built since the development of company housing early in this century. During the period of decline in employment, many company houses and towns were destroyed, and in parts of Appalachia miners face critical housing problems. Although companies sold their remaining houses to miners and their families, most were unwilling to sell land. Securing land for building is a great problem, and chronic flooding in the mountains makes much of the available land unsafe and unusable (see Figure 13).

Many miners and families have built houses outside the coalfields and commute long distances to work. Miners travel an average of 26 miles to work, twice as far as other rural workers. Others have relied on mobile homes, which require less land and are more readily available. Thirty percent of the Appalachian miners live in mobile homes.

Although the miner is well paid and seeks to maintain a middle-class life style, many mining communities lack the facilities and services available in other industrial areas. The long history of underdevelopment and neglect of coalfield communities has left a heritage of bitterness and distrust that continues to affect labor relations in the coalfields. Despite the high wages for individual working miners, coal mining communities in general continue to have lower than average family incomes and high rates of poverty for the rest of the population, which for the most part derives its income from the coal industry.

HISTORY OF LABOR ORGANIZATION IN THE COAL INDUSTRY

The first known coal miners' union in the United States was the American Miner's Association, which was formed in 1861. It was unable to survive for long, however, because of the competitive nature of the coal industry, which was made up of small producers. These small producers chronically produced more coal than the current demand for it, leading to falling prices and pressure on producers to reduce the wages of their employees. The association found it impossible to survive under these market conditions.

There were other attempts to form unions of coal miners in the next few years, but none survived for long until the National Federation of Miners and the National Trades Assembly No. 135 of the Knights of Labor created the United Mine Workers of America (UMWA) in 1890. In 1898 John Mitchell, one of the UMWA's earliest presidents, negotiated the Central Competitive Field Agreement with coal operators in Illinois, Indiana, Ohio, and western Pennsylvania. It provided for protection from the swings in wages that resulted from uncertain market conditions.

FIGURE 13 Lundale, Logan County, West Virginia, a typical coal mining community.

This agreement was renegotiated at fairly regular intervals for nearly 30 years. But increased production from nonunion areas in West Virginia, Kentucky, and Virginia throughout the 1920s led to the collapse of the agreement in 1927. Labor organizing in the coalfields was characterized by struggle; bitter "mine wars" between operators and miners remain part of the coalfield history of the late nineteenth and early twentieth centuries.

As a result of price competition from unorganized areas and a dwindling demand for coal, many coal operators in the areas covered by the field agreement went bankrupt or demanded wage cuts from their miners. Membership in the UMWA dropped from a peak of 405,000 in 1923 to less than 200,000 by 1930. John L. Lewis had become president of the UMWA in 1920 and presided over this period of steep decline in membership. As might be expected, Lewis was charged by challengers to his presidency for the decline in membership and for the inability to organize areas where high production was creating price instability.

However, by adroit political maneuvering he survived such challenges and became the undisputed leader of the union by the end of the 1920s. It was during this period that a rival to the UMWA was formed. As a result of competition from unorganized areas, Lewis accepted wage cuts for members in District 12, which covers Illinois. Members of the district resisted and formed the Progressive Miners of America in 1932, later changing their name to the present one, the Progressive Mine Workers of America.

The fortunes of the UMWA improved dramatically after 1933 as a result of the passage by Congress of the National Industrial Recovery Act. A key provision of the act protected the right of employees to organize. Although the Supreme Court was later to rule the act unconstitutional, this provision became part of the National Labor Relations (Wagner) Act in 1935. By 1934 the UMWA was able to sign agreements that covered not only the states that were once included in the Central Competitive Field Agreement but also states that it had been unable to organize previously: West Virginia, Virginia, Maryland, eastern Kentucky, and northern Tennessee. It was also able to sign agreements covering coal from captive mines, mines owned by a company whose primary business is in another field, for example, steel or electricity.

During and immediately following World War II the UMWA clashed several times with the federal government. In 1943 Lewis challenged the authority of the National War Labor Board to dictate a settlement with coal operators. He initiated a strike in defiance of a no-strike pledge during wartime. President Roosevelt ordered the mines seized, and Secretary of the Interior Harold Ickes negotiated an agreement with Lewis. Public sympathy was against the UMWA during this time, and the strike contributed to the passage of the Smith-Connally Act, which made it illegal to strike against government-operated plants.

In 1946, while wartime provisions were still in effect, the UMWA went out on strike. Now President Truman ordered the mines seized, and Secretary of the Interior Julius Krug negotiated with Lewis. The most significant outcome of these negotiations was the creation of the UMWA Health and Benefit Fund.

Several strikes occurred between 1947 and 1949, and President Truman invoked strike injunctions against the UMWA under the newly enacted Taft-Hartley Act. This period of labor unrest culminated in the signing of the

National Bituminous Coal Mine Agreement in 1950. This agreement is noteworthy first because it was the first industry-wide agreement. This meant in effect that the major operators and captive mines signed a master agreement that was also accepted by most small operators who did not belong to the Bituminous Coal Operators Association (BCOA). Second, it ushered in a period of increased mechanization at a time when the demand for coal was declining. Naturally, coal employment dropped as a consequence, but Lewis contributed to labor peace at this time because he believed that mechanization was necessary for the long-term survival of the coal industry, and because the UMWA Health and Benefit Fund made it possible for those employees displaced from the mines to sustain themselves economically. By 1969 employment in the coal industry had dropped to 125,000 workers.

John L. Lewis retired from the UMWA presidency in 1960. After the brief tenure of Thomas Kennedy, W. A. "Tony" Boyle became president in 1963. Dissatisfaction with Boyle's conduct of union affairs grew quickly, and he was challenged for the union presidency in 1969 by Joseph "Jock" Yablonski. Although Boyle won the presidential election, Yablonski, his wife, and their daughter were murdered shortly afterward. Suspicions of Boyle's complicity and of irregularities in the election led to a court-ordered new election under provisions of the Labor Management Reporting and Disclosure Act (the Landrum-Griffin Act) of 1959. Arnold Miller won the new election, which was held in 1972.

In 1973 the constitution of the UMWA was changed to guarantee the election of district officials (previously the president had the authority to dismiss them) and to permit rank and file ratification of agreements. A bargaining council made up of the members of the International Executive Board and the presidents of the 18 districts, which are directly involved with the BCOA, has to approve the proposed agreement negotiated by the principal union officers and their staff before the agreement is submitted to the membership for ratification.

Due in part to this new arrangement and to other socioeconomic factors, labor relations in the coal industry have become less stable than they were under John L. Lewis. The president and his bargaining team have difficulty gaining approval from the bargaining council, which is now made up of persons with independent political bases, who either have political ambitions of their own or might be willing to enter into coalitions with others to weaken the president's position. A lack of support by key district officials combined with inadequate means of communicating with the membership about the meaning and consequence of proposed contract provisions contributed to the narrowness of ratification of the 1974 agreement and to the initial defeat of the proposed 1978 and 1981 agreements.

The number of wildcat strikes increased significantly after 1973, peaking in 1977 (Wall Street Journal, June 20, 1977). A weakening of the office of the president may be a contributing factor, in that his pleas for workers to stay or return to work go unheeded. The influx of young miners into the industry in the middle 1970s may represent a shift toward less toleration of existing management practices than was felt by the miners who are retiring. General distrust of the grievance process is one of the major contributors to wildcat strikes (Dominion Post, Morgantown, West Virginia, May 31, 1977).

Changes in the 1978 agreement that permit supervisors to settle grievances directly without seeking higher approval and without setting precedents may have helped stem the number of wildcat strikes since 1977. The creation of the Arbitration Review Board in 1974 and its modification in 1978 have been attempts toward improvement. The board is made up of a representative from the UMWA, a representative from the BCOA, and a neutral third party and has the authority to review arbitration awards submitted to it as a final appeal. Finally, a stabilization of the influx of new miners into the industry and increased knowledge about existing grievance procedures among those already employed may have also helped stabilize labor relations in the industry.

The Role of the UMWA in Safety

Unions generally and the UMWA in particular have been strong advocates of safety in coal mines. The UMWA worked vigorously for enactment of the Mine Safety and Health Acts of 1969 and 1977 and views their effort to be justified by the decrease in fatalities and disasters that ensued.

Today the UMWA safety division is responsible for drafting the union's position on legislative matters and for handling legal problems that arise from safety regulations and members' grievances. Reporting to the division are 56 inspectors in the field and about 4,000 safety committeemen in mines the UMWA represents. Safety training, formerly a responsibility of the division, is now under a separate training department.

In recent years all of the UMWA-industry wage agreements contain provisions for committees dedicated to safety improvement and safety training. The National Bituminous Coal Wage Agreement of 1981 (United Mine Workers of America, 1981) continued in force the provision in prior contracts for a Joint Industry Health and Safety Committee and a Joint Industry Training Committee, both at the national level. It also continued the Mine Health and Safety Committees at all UMWA mines.

The Mine Health and Safety Committees are selected by the local union. The committees are authorized to inspect the mine and to shut down areas of imminent danger to employees. They are charged to meet monthly with management representatives to review safety issues.

The Joint Industry Health and Safety Committee, consisting of three union and three industry representatives, has studied selected safety problems such as lighting requirements, self-rescuers, cabs and canopies for mobile equipment, etc. The Joint Industry Training Committee also has three union and three industry representatives. It gives special attention to the training problems of employers having three or fewer mines by developing training programs for those small companies (United Mine Workers of America, 1981).

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4

STATISTICAL ANALYSES AND CASE STUDIES

INTRODUCTION AND SUMMARY

This chapter presents the Committee's statistical analyses of data on coal mine injuries, including fatalities. The objectives are to determine patterns and trends in the incidence of disabling injuries and to identify characteristics of mines that correlate with injury rates. The raw data used to carry out the analyses were obtained primarily from merging two distinct computer files maintained by the Health and Safety Analysis Center (HSAC) of the Mine Safety and Health Administration (MSHA) in Denver, Colorado. In addition, information on the age distribution of miners was obtained from a survey we carried out of the largest coal-producing companies.

An important consideration in our analyses of these data was the uniformity between mines in the reporting of nonfatal disabling injuries. Several safeguards were taken to minimize potential problems due to incomparability of reported injury statistics between mines: (1) analyses of nonfatal disabling injuries were restricted to the years 1978-80, after the introduction of legislation that improved the accuracy and uniformity of reporting practices; (2) no distinction was made between those degrees of severity of disabling injuries that were determined by the Committee to depend more on a mine's policy than on actual severity; (3) no use was made of data on durations of injuries, as these were felt to depend a great deal on policy and local regulations; and (4) a new measure of injury rate, the intermediate injury rate, designed to be relatively insensitive to reporting differences between companies was used in addition to the traditionally used injury rates. We were also cautious in our assessment of the importance of individual mine characteristics for safety, viewing with suspicion those correlations that were weak and inconsistent.

Disabling injuries are classified by the degree of severity and by the type of accident resulting in the injury. The two most severe degrees, consisting of fatalities and permanent disabilities, account for about 2 percent of the approximately 13,000 disabling injuries occurring each year. In our analysis the accidents that cause disabling injuries were grouped into seven categories: roof/side falls, haulage, machinery, electrical/explosive, material handling, slipping/bumping, and others. Although the first four of these categories account for only 41 percent of all disabling injuries, they account for virtually all (98 percent) fatalities. Mines with higher rates of nonfatal disabling injuries were also found to be at greater risk for fatal injuries.

Our analyses of injury rates yielded several important findings. First, the finding of the President's Commission on Coal that mines with 50 or fewer employees have a higher fatality rate than larger mines was confirmed and extended in our analyses. The data in fact show that an increased risk of fatalities is not limited to mines with fewer than 50 employees, but that it decreases steadily with mine size. Mines with fewer than 50 employees have nearly three times the fatality rate of mines with over 250 employees, and nearly twice the fatality rate of medium-sized mines (50-250 employees). This association between mine size and fatalities was found in all the fatality data we examined back to 1970. It could not be explained by any of the other mine characteristics we examined, nor can it be explained in terms of large mines having more employees away from the working face than small mines.

The age of miners was found to be strongly correlated with disabling injury rates. Young miners (18-24 years old) have about three times the injury rate of miners over 45, and about twice the injury rate of miners between 25 and 44. This association was consistent across the 15 companies and for each of the three years for which we had data.

There were extremely large differences in injury rates between the 19 major coal-producing companies we examined. These differences could not be explained by geology, geography, age, or other factors we considered but appear to be due to factors internal to the companies. Examinations of trends over time indicate that some companies are maintaining or improving their safety records, but others have rates that are deteriorating. Case studies of one company whose injury rates have dramatically improved and two others whose rates have stayed at better than average levels for several years suggest that a strong commitment to achieving safety by the highest levels of management and the institution of a well-run safety program are primary factors in reducing injury rates; they also suggest that once appropriate management changes are made, injury rates can be substantially improved in a relatively short time.

A comparison of the seven large underground coal mining states reveals that Kentucky has a substantially lower disabling injury rate than the others, and this cannot be explained by state differences with respect to companies, seam thickness, mine size, or unionization status. Virginia has a larger fatality rate than the other major coal-producing states. Some, although not all, of this higher rate is due to a greater proportion of smaller mines in Virginia than in the other states. The overall fatality rate in nonunion mines is nearly twice that in union mines. However, the entire difference can be explained by the fact that nonunion mines are predominantly small, whereas union mines tend to be large. It was also observed that the disabling injury rate in union mines is considerably larger than that in nonunion mines. However, examination of an alternative injury rate statistic designed to be relatively insensitive to reporting inconsistencies suggests that the difference between union and nonunion disabling injury rates is largely a reporting phenomenon.

Overall, mines with higher productivity were found to have lower injury rates than mines with lower productivity. This negative association was attenuated after adjustment for other mine characteristics, but nonetheless demonstrates that productivity and safety can be compatible entities.

DATA BASE, MEASURES OF SAFETY, AND REPORTING CONSISTENCY

The data in the HSAC computer files are obtained from two kinds of reports routinely submitted to MSHA by each mine: the employment/production report and the accident/injury/illness report. The report forms are reproduced in Appendix 4-A to this chapter. An employment/production report is submitted quarterly and provides information on mine status, seam height, production, and employment for the quarter. An accident/injury/illness report is submitted each time someone is involved in an accident requiring medical attention or resulting in lost time from that person's ordinary job. The report contains information about the nature of the accident, about the injury, and about the person who was injured. MSHA maintains yearly computer tapes of these reports dating back to 1972. The primary data base used in our analyses was created by merging each accident/injury/illness report with the corresponding employment/production report. Two percent of the accident/injury/illness reports had no corresponding employment/production report, so these were not included in our analyses. As a result, the total counts presented in this chapter are somewhat smaller than those presented in Chapter 3. We also obtained data on union status and on the age of miners. Union status was obtained from MSHA district office records. Age information was obtained from a survey we carried out of 15 of the largest coal-mining companies (see Appendix 4-C). This provided the age distribution of miners on a company-wide basis but not separately for each mine.

HSAC classifies each injury according to its degree of severity. The categories are explained in detail in Appendix 4-B. The five categories of disabling injury, in which a worker does not return to his usual job during the same shift, are described in Table 9.

Each injury is also classified by the type of accident that caused it. The 21 specific accident types are also described in Appendix 4-B. Many of these specific types of accidents occur very infrequently, so the 21 categories were collapsed into the 7 broader categories shown in Table 10.

Prior to 1978 the information to be collected by MSHA was determined by Part A of the 1969 Mine Safety and Health Act. It was generally felt that the reporting of disabling injuries for this period was inconsistent between mines, and therefore not well suited for mine-to-mine comparisons.*

The 1977 amendments to that act (specifically CFR Title 30, Part 50) appear to have created greater uniformity and consistency in reporting between mines. Consequently, our

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*See, for example, Office of Technology Assessment (1979) The Direct Use of Coal: Prospects and Problems of Production and Combustion, U.S. Government Printing Office, Washington, D.C., pp. 286-290 and the references therein.

TABLE 9 Disabling Injuries by Category

Degree of Severity	Description
Degree 1	Fatal injury
Degree 2	Permanent disability (total or partial)
Degree 3	Lost time from work
Degree 4	Lost time from work and time spent in a restricted activity
Degree 5	Time spent in restricted activity

TABLE 10 Types of Accidents by Category

Type	Called	HSAC Categories	Description
1	Roof/side fall	2, 5, 6, 7	Fall of roof, side, or face; falling, sliding, or rolling rock or other material; entrapment
2	Haulage	11, 12, 13, 15	Powered or nonpowered haulage; hoisting; impoundment
3	Machinery	17	Motion of machinery
4	Electrical/ explosive	1, 3, 4, 8, 14, 16	Electrical; exploding vessels; explosives, fire; ignition; inundation
5	Material handling	9	Lifting, pulling, pushing; shoveling
6	Slipping/ bumping	10, 18, 19, 20	Slips or falls of a person; striking or bumping an object; hand tools; stepping or kneeling on object
7	Other	21	Other types of accidents

analyses of nonfatal disabling injuries are based on the three-year period 1978-80. Fatalities, which were considered to be accurately reported prior to 1977, are an exception to this rule. Hence for fatalities we used data for the years 1970-80 in certain analyses.

Our basic measure for evaluating safety is the injury rate, defined in terms of the number of employee-hours of work over a certain period and the number of injuries that occur during that period. The injury rate is the number of injuries per 200,000 employee-hours. The factor 200,000 is approximately the number of hours worked by 100 full-time employees during a year. Thus an injury rate of 12 would correspond to 12 injuries among 100 workers in the course of a year. Depending on what kinds of injuries are included in the numerator of this ratio, several kinds of injury rates can be determined. We use the symbol R to indicate an injury rate and consider the kinds of rates shown in Table 11.

R_D is the usual disabling injury rate used by MSHA, consisting of all disabling injuries (degrees 1-5). R_1 and R_2 are the rates of fatal injuries and of injuries causing a permanent disability, respectively. R_{INT} is an "intermediate" injury rate, comprising all fatal and permanent disability injuries as well as all injuries resulting from roof/side falls, machinery, haulage, or electrical/explosive accidents.

We base our comparisons on injury rates because they entail a comparison of numbers of injuries normalized by employee-hours of exposure. Comparisons that are not normalized by exposure can be quite misleading and in general should be regarded with suspicion. For example, to observe that 99 percent of those injured in coal mines are men and to conclude from this alone that a male miner is more injury-prone than a female miner is clearly erroneous, because the numbers of injuries are not standardized by the numbers of man-hours and woman-hours. A severe limitation we found with much of the injury literature is that analyses are based on non-normalized statistics.

The validity of mine-to-mine comparisons based on injury rates hinges on the consistency between mines in their reporting of accidents. There is little doubt that fatalities and permanent disabilities are reported to MSHA; hence it is felt that there are no comparability problems for R_1, R_2, or R_{12}. These rates are also especially meaningful because they represent the most serious injuries. However, they are of only limited value for statistical purposes, because relative to degree 3, 4, and 5 injuries, fatalities and permanent disabilities occur very infrequently (amounting to approximately 100 and 200 per year across the industry, respectively). Consequently, we also used the disabling injury rate, which includes many more injuries.

One consideration when examining the consistency in reporting between mines is the distinction among degree 3,

TABLE 11 Names and Definitions of Injury Rates

Name	Symbol	Kind of Injuries Included
Disabling injury rate	R_D	Degree 1-5 injuries
Fatality rate	R_1	Degree 1 injuries (fatalities)
Permanent disability rate	R_2	Degree 2 injuries (permanent disabilities)
Fatality and permanent disability rate	R_{12}	Degree 1 and 2 injuries ($R_{12} = R_1 + R_2$)
Intermediate injury rate	R_{INT}	Injuries that are either degree 1 and 2 or that result from accident types 1-4

4, and 5 injuries. Whereas fatalities (degree 1) and permanent disability injuries (degree 2) are more severe than degree 3, 4, or 5 injuries, any distinction among the latter is, in our opinion, more a matter of a company's policy than an injury's severity.* Accordingly, in an effort to improve comparability, we hereafter make no distinction between degree 3, 4, and 5 injuries.

Another concern regarding consistency in reporting is that some mines may be more apt than others to report certain less serious injuries. If so, the two mines could be equally safe yet appear different when compared according to reported injuries. Since we were concerned about consistency between mines in reporting all degree 3-5 injuries, we introduced the intermediate injury rate (R_{INT}). This rate includes all injuries except those degree 3-5 injuries due to material handling (type 5), slipping/bumping (type 6), or other (type 7) accidents. The rationale for defining R_{INT} in this way rested on the belief that reporting inconsistencies would occur most

*Most companies make little use of restricted duty for employees who suffer a disabling injury, and thus these injuries are almost always classified as degree 3. A few companies, however, make extensive use of restricted activity, and as a result many of their otherwise degree 3 or degree 4 injuries are classified as degree 5. Therefore failure to include degree 5 injuries in the definition of an injury rate tends to make these companies appear safer, relative to other companies, than they in fact are.

frequently for the degree 3-5 material handling and slipping/bumping injuries. Consequently, for consistency in reporting, R_{INT} is felt to lie somewhere between R_{12}, where reporting inconsistencies are felt to be negligible, and R_D, where they might not be. We thus regard R_{INT} as a compromise measure of safety that includes ample numbers of injuries for most statistical purposes and provides for reasonably good consistency between mines in the reporting of injuries.

Other measures of safety could have incorporated nondisabling injuries (degree 6 injuries) or allowed for the duration of injuries. We examined the first of these options and concluded that including degree 6 injuries would have little, if any, effect on our results. The use of durations of injuries raised potentially serious questions about comparability. The number of lost or restricted days resulting from an injury depends in a complicated way on company policy, state compensation laws, and other factors, and hence could vary considerably between certain mines within a company or between companies. For these reasons we did not use durations of disabling injuries in our analyses.

GENERAL PATTERNS AND TRENDS IN INJURIES

This section describes the frequency, severity, and types of injuries that are occurring in underground coal mining, the relationship between the severity of an injury and the type of an accident, and the correlation between the types of injury rates used in our analyses.

Frequency, Severity, and Type of Injury

Table 12 gives the distribution of reportable injuries by degree of injury and type of accident for the period 1978-80. The data in the table are based on 3,189 underground mines, of which over 80 percent are very small, employing 50 or fewer employees; together these small mines account for 16 percent of all underground employee-hours. In contrast, 4 percent of the mines employ at least 250 employees, yet account for nearly half of all employee-hours. Moreover, many of the small mines remain active only for a short period of time, so the number of mines active at any time is considerably less than 3,189. For example, there were 1,707 active mines during the fourth quarter of 1980.

TABLE 12 Distribution of Reportable Injuries by Degree of Severity and Type of Accident for 1978-80

Type of Accident	Degree of Severity Degree 1	Degree 2	Degree 3-5	All Degrees
1. Roof/side falls	120	29	3,597	3,746 (10%)
2. Haulage	57	92	5,285	5,434 (14%)
3. Machinery	20	126	5,152	5,298 (14%)
4. Electrical/ explosive	34	2	974	1,010 (3%)
5. Material handling	2	242	12,755	12,999 (34%)
6. Slipping/bumping	2	47	8,993	9,042 (24%)
7. Other	1	5	567	573 (1%)
All accident types	236	543	37,323	38,102 (100%)
Injury rate	0.07 (.005)	0.17 (.01)	11.8 (.1)	12.0 (.1)

NOTE: Data are based on 3,189 underground mines, accounting for 634.3 million employee-hours of underground labor. Rates are average number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors.

During the three-year period, which involved 634.3 million employee-hours, there were 38,102 reportable injuries, of which 236 were fatal and 543 produced permanent disabilities. Together, fatal and permanently disabling injuries account for about 1 in every 50 injuries. The most common accident types are material handling and slipping/bumping, which in combination account for 58 percent of all injuries.

Note that 98 percent (231/236) of all fatal injuries are due to accidents of the first four types, even though these types account for only 41 percent of all injuries. Put another way, a type 1-4 accident is 67 times more likely to be fatal than is a type 5-7 accident. In this sense, accident types 1-4 can be regarded as being more serious than accidents associated with material handling (type 5) or slipping/bumping (type 6). On the other hand, permanent disability injuries are not nearly so strongly correlated with accident types. Here a nonfatal type 1-4 accident is only 25 percent more likely to result in a permanent disability than is a nonfatal type 5-7 accident (249/15,257 versus 294/22,614).

Table 13 gives the overall disabling injury rates (R_D), the intermediate injury rates (R_{INT}), and the type-specific injury rates on a yearly basis between 1978 and 1980. For example, the overall rate of 10.9 in 1978

TABLE 13 Annual Injury Rates by Type of Accident for 1978-80

Type of Accident	1978	1979	1980
Roof/side fall	1.2	1.1	1.2
Haulage	1.6	1.7	1.8
Machinery	1.5	1.7	1.8
Electrical/explosive	0.3	0.3	0.3
Material handling	3.7	4.3	4.2
Slipping/bumping	2.4	2.9	3.2
Other	0.3	0.2	0.1
Total injuries	10,281	13,940	13,881
Employee-hours (millions)	188.6	226.3	219.4
Disabling injury rate (R_D)	10.9 (.1)	12.3 (.1)	12.7 (.1)
Intermediate injury rate (R_{INT})	4.6 (.1)	5.0 (.1)	5.3 (.1)

NOTE: Rates are number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors. Estimated standard errors of all other rates are less than .05.

means that, on the average, there were 10.9 reportable injuries for every 100 full-time workers during that year. The type-specific rates indicate how many of these correspond to each accident type. Note that there was a 13 percent increase in the disabling injury rate (from 10.9 to 12.3) between 1978 and 1979. This was attributable primarily to material handling and slipping/bumping accidents, which rose 18 percent between 1978 and 1979. This entire increase might be real, but it is likely due in part to companies adjusting to the changes in injury reporting required by the 1977 amendments to the 1969 Mine Safety and Health Act.

Multiple-Fatality Accidents

The overwhelming majority of fatal accidents involve a single fatality. Of the 236 fatalities occurring between 1978 and 1980 that are summarized in Table 12, 204 (86 percent) were the result of an accident in which a single miner was killed. The remaining 32 fatalities were the result of 11 multiple-fatality accidents. Between 1972 and 1980, 16 percent (or 38) of the fatal accidents involved multiple fatalities: 22 accidents involved two deaths, 13 accidents involved three to five deaths, and 3 accidents involved more than five deaths (9, 9, and 23 deaths in 1972, 1977, and 1976).

Note than an alternative fatality statistic to R_1 is the fatal accident rate, defined similarly to R_1 but only in terms of fatal accidents rather than total fatalities. However, because the large majority of fatal accidents involve a single fatality, and because accidents with more than five fatalities are so rare, our analyses would lead to the same conclusions using the fatal accident rate as using R_1.

Relationships Between Injury Rates

This section investigates whether mines having a higher rate of one kind of injury (e.g., nonfatal intermediate injuries) also have higher rates of other kinds of injuries (e.g., fatalities).

To assess this issue each mine was classified into one of four categories, depending on whether its intermediate injury rate (R_{INT}) was 0-2, 2-4, 4-6, or over 6. Values for R_1, R_2, and R_D were then determined for the combined information within each category. The results are given in Figure 14, where we have plotted R_1, R_2, and $R_D - R_{INT}$ versus R_{INT}. The points denoted by solid circles indicate that mines having larger intermediate injury rates also have larger nonintermediate disabling injury rates ($R_D - R_{INT}$), which essentially represent the degree 3-5 injuries resulting from material handling or slipping/bumping accidents. The rising line segments corresponding to R_1 and R_2 similarly indicate that mines having larger intermediate injury rates also have higher fatality rates and higher permanent disability rates.* These results are very important because they

*Since a fatality is also an intermediate injury, R_{INT} consists in part of R_1. In such circumstances a plot of R_1 versus $R_{INT} - R_1$ is more appropriate than one of R_1 versus R_{INT}, since the latter can suggest an association when none really exists. However, fatalities form such a small proportion of intermediate injuries that a plot of R_1 versus R_{INT} is virtually equivalent to one of R_1 versus $R_{INT} - R_1$. Similar arguments apply to R_2.

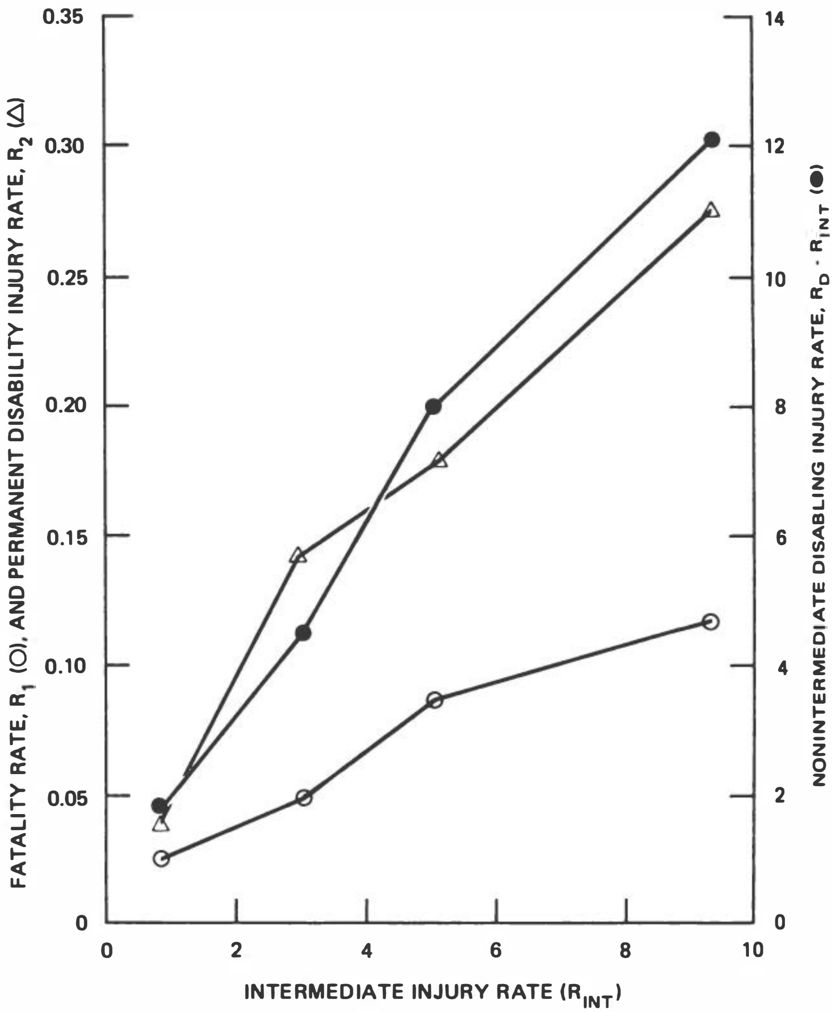

FIGURE 14 Fatality rates (R_1), permanent disability injury rates (R_2), and nonintermediate disabling injury rates (R_D - R_{INT}) for mines grouped by intermediate injury rates. Mine injury rates are based on pooled 1978-80 data. Grouping intervals for R_{INT} are 0-2, 2-4, 4-6, and over 6. Estimated standard errors for R_1, R_2, and R_D - R_{INT} are no more than .01, .02, and .1, respectively.

indicate that mines with large intermediate or disabling injury rates also present a greater risk for a fatality or permanent disability.

CORRELATES OF INJURY RATES

This section examines the association of several mine and miner characteristics with injury rates. The characteristics examined are mine size, seam thickness, union status, productivity, location by state, and miner's age. The two most striking findings relate to mine size and the age of miners. Mine size is seen to be strongly correlated with fatality rates: Workers in smaller mines are at substantially greater risk of a fatal injury. Also, the age of workers is seen to be strongly correlated to disabling injury rates, with young miners (ages 18 to 24) having a much higher disabling injury rate than older miners.

Our analyses of these mine characteristics consisted in part of multiple regression techniques designed to assess the combined importance of several characteristics simultaneously. For simplicity and clarity, the details of the regression techniques are deferred to Appendix 4-D and our presentation focuses on each characteristic separately, introducing combined associations with other characteristics only when necessary to explain a trend or effect.

Mine Size

Each mine was grouped into one of four size categories on the basis of the number of underground employees.* Table 14 gives the fatality rates (R_1), the permanent disability injury rates (R_2), the intermediate injury rates (R_{INT}), and the disabling injury rates (R_D) by category. There are no substantial differences between the different size categories with respect to R_2 or R_{INT}. Since there is no evidence that the intermediate injury

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*In Table 14 the size for a particular mine is the median number of employees reported in the 12 quarterly employment reports filed for the mine between 1978 and 1980. Similar results are obtained when using other measures of mine size, such as the average over 12 quarters or each quarter separately.

TABLE 14 Injury Rates by Mine Size for 1978-80

	Number of Employees			
	1-50	51-150	151-250	Over 250
No. of mines	2,620	314	119	136
Employee-hours (millions)	100.9	129.1	111.1	293.2
Disabling injuries	4,848	7,968	6,298	18,988
Intermediate injuries	2,595	3,504	2,588	7,100
Permanent disabilities	88	100	99	256
Fatalities	71	55	40	70
Disabling injury rate (R_D)	9.6	12.3	11.3	13.0
Intermediate injury rate (R_{INT})	5.1	5.4	4.7	4.8
Permanent disability rate (R_2)	0.18 (.02)	0.15 (.02)	0.18 (.02)	0.17 (.01)
Fatality rate (R_1)	0.14 (.02)	0.09 (.01)	0.07 (.01)	0.05 (.01)

NOTE: Rates are number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors. Estimated standard errors of R_D and R_{INT} are all less than .15.

rate is larger for large mines, the somewhat smaller disabling rate for mines having 50 or fewer employees may be a reporting phenomenon.

The most striking observation in Table 14 is the association between fatality rate and mine size. The fatality rate for mines with 50 or fewer employees (0.14) is about three times that of mines with over 250 employees (0.05), and almost twice that of mines with 51-250 employees. To get a feel for the magnitude of these differences, note that if mines with 250 or fewer employees, which account for 54 percent of all employee-hours, had the same fatality rate as mines with over 250 employees, then the total number of fatalities in these smaller mines between 1978 and 1980 would have been 81 instead of 166. Similarly, if mines with 50 or fewer employees had the same fatality rate as mines with over 50 employees, their number of fatalities would have dropped from 71 to 38. These results confirm and extend those of the President's Commission on Coal, which examined 104 fatalities and found that mines with 50 or fewer employees had a higher fatality rate than did larger mines.

This strong association between fatality rate and mine size could not be explained by any of the other mine characteristics that we examined. Moreover, it was apparent in fatality data from all previous years we could obtain. Table 15 gives R_1 by mine size since 1969, with data grouped into three-year intervals.* Note from the table that the fatality rates for mines within each size category, as well as the overall fatality rate, have dropped since the passage of the Mine Safety and Health Act in 1969. Since 1969 there has been a modest increase in the number of small mines, as measured by employee-hours. However, this has had a negligible impact on the decline in overall fatality rates: The corrected rates for the four three-year intervals between 1969 and 1980, adjusted to the size distribution that prevailed in 1978-80, are 0.18, 0.12, 0.10, and 0.07.

Table 16 gives a breakdown of fatalities occurring in 1978-80 by size and type of accident. The distribution of fatalities is similar within each size category. This indicates that the larger fatality rate in small mines is not due to an increase in fatalities of a particular type (e.g., roof falls). Rather, smaller mines tend to have proportionally more fatal accidents of all types than do larger mines.

A partial explanation for the association between mine size and fatality rates may have to do with a size-related trend in the proportion of underground workers at high risk for a fatal accident. It is generally accepted that the proportion of underground miners in proximity of the working face is greater in smaller mines than in larger mines. Thus if workers near the face are at substantially greater risk than those away from the face, larger mines would tend to have smaller fatality rates simply because their workforces include a greater proportion of low-risk miners than do those of small mines.

Unfortunately, we did not have the kind of data needed to determine precisely how much, if any, of the observed association between mine size and fatality rates is due to this phenomenon. However, crude techniques can be used to get a feel for the maximum amount of association that can be explained by such an argument. We estimate that the proportions of miners in proximity of the working face

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*Data for 1969-74 were obtained from Bureau of Mines reports entitled Injury Experience in Coal Mining, in which annual mine size is determined by the average over four quarterly reports.

TABLE 15 Fatality Rate (R_1) by Mine Size for Three-Year Intervals Between 1969 and 1980

	Number of Employees								All Mines
	1-50		51-150		151-250		Over 250		
Period	R_1	Percentage of Hours	R_1	Percentage of Hours	R_1	Percentage of Hours	R_1	Percentage of Hours	R_1
1969-71	0.34 (.03)	19	0.27[a] (.02)	22	0.17	24	0.10	35	0.20
1972-74	0.29 (.03)	11	0.10	21	0.08	20	0.09	48	0.12
1975-77	0.18 (.02)	13	0.11	19	0.07	18	0.07	50	0.09
1978-80	0.13 (.02)	16	0.09	20	0.08	17	0.05	47	0.07

[a]Includes a single accident involving 38 fatalities, without which the rate would equal 0.20. No other rate differs by more than 0.02 from the corresponding fatal accident rate.

NOTE: Fatality rate equals average number of fatalities per 200,000 employee-hours. Numbers in parentheses are estimated standard errors. All other rates have estimated standard errors of .01 or less.

TABLE 16 Numbers of Fatalities by Type of Accident and Mine Size for 1978-80

Type of Accident	Mine Size (number of employees) 0-50	51-150	151-250	Over 250	Total
Roof/side falls	37 (52%)	22 (40%)	22 (55%)	39 (56%)	120 (51%)
Haulage	15 (21%)	19 (35%)	8 (20%)	15 (21%)	57 (24%)
Machinery	9 (13%)	4 (7%)	2 (5%)	5 (7%)	20 (8%)
Electrical/explosive	8 (11%)	9 (16%)	8 (20%)	9 (13%)	34 (14%)
Material handling	0	1	0	1	2
Slipping/bumping	2	0	0	0	2
Other	0	0	0	1	1
Total	71	55	40	70	236

NOTE: Numbers in parentheses are column percentages.

are 80 percent, 70 percent, 60 percent, and 50 percent in mines with 1-50, 51-150, 151-250, and over 250 employees (based on estimates from one large company and a mining management consultant). Suppose, as an extreme case, that miners away from the face were at zero risk for a fatality. Then the adjusted fatality rates from Table 16, applicable only to miners near the working face, would be 0.18, 0.13, 0.12, and 0.10, respectively, for the four size categories. Hence, even in this "worst case" situation, adjustment for the low-risk phenomenon still leaves a very strong association between mine size and R_1. We therefore feel that while a portion of the association between mine size and fatality rate is due to large mines having proportionally fewer workers at the face, this phenomenon explains only a relatively small amount of the association.

Seam Thickness

Each mine was grouped into one of five categories based on the seam height given in the quarterly address/employment reports (in situations where a mine's seam thickness changed over the period 1978-80, its median seam thickness was used). Table 17 gives the injury rates R_1, R_2, R_{INT}, and R_D by categories of seam thickness. Omitted are mines that did not report the thickness of their seams.

No clear trends emerge from the table. Mines having a seam thickness of 48 in. or less have slightly higher

TABLE 17 Injury Rates by Seam Thickness for 1978-80 (not adjusted for mine size)

	Seam Thickness				
	48 In. or Less	49 to 60 In.	61 to 72 In.	73 to 84 In.	Over 84 In.
Employee hours (millions)	110.0	127.8	97.4	87.4	80.9
Fatalities	51	41	24	34	25
Permanent disabilities	109	112	65	92	75
Intermediate injuries	3,196	3,091	2,325	2,108	1,939
Disabling injuries	7,748	7,794	6,228	5,446	4,633
Fatality rate (R_1)	0.09 (.01)	0.06 (.01)	0.05 (.01)	0.08 (.01)	0.06 (.01)
Permanent disability rate (R_2)	0.20 (.02)	0.18 (.02)	0.13 (.02)	0.21 (.02)	0.19 (.02)
Intermediate injury rate (R_{INT})	5.8	4.8	4.8	4.8	4.8
Disability injury rate (R_D)	14.1	12.2	12.8	12.5	11.5

NOTE: Rates are average number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors. Estimated standard errors of R_D and R_{INT} are all less than .2.

fatality and disabling injury rates than do mines with seam heights over 48 in. However, the larger fatality rate for these mines can be explained by the fact that most are small; once mine size is accounted for, there is no residual association between seam thickness and fatalities. The larger disabling injury rate in mines with seam thicknesses of 48 in. or less cannot be explained by other mine characteristics. However, the difference is sufficiently small that we are reluctant to place much emphasis on it.

Union Status

A mine's union status is not recorded on the MSHA employment/production or accident/injury/illness records; however, we were provided with this information by MSHA through their district office records. Table 18 gives injury rates for mines grouped as union or nonunion. The United Mine Workers (UMW) union accounts for 98 percent of the employee-hours among the union mines; the remaining 2 percent is made up of four small unions. Since the UMW accounts for nearly all the union data, the same injury rates would result if we restricted attention only to the UMW union mines. Excluded from the table are mines, accounting for 47.8 million employee-hours, for which union status could not be obtained.

Note that the disabling injury rate for union mines (12.7) is larger than that for nonunion mines (7.6). The corresponding intermediate injury rates, however, are very similar. Thus the difference in overall injury rates is due primarily to the fact that union mines have more than twice the rate of injuries from material handling and slipping/bumping accidents. Recall that R_{INT} was introduced to be less sensitive to reporting differences than R_D. Since there is no substantive reason to expect union and nonunion mines to differ only with respect to nonintermediate disabling injuries (i.e., degree 3-5 injuries from material handling and slipping/bumping accidents), it appears likely that the difference between union and nonunion disabling injury rates is primarily a reporting phenomenon.

The second striking aspect of Table 18 is that the fatality rate in nonunion mines is nearly twice that in union mines (0.11 versus 0.06). However, it is also apparent that nonunion mines tend to be smaller than union mines. Since mine size was previously found to be asso-

TABLE 18 Injury Rates by Union Status for 1978-80 (not adjusted for mine size)

	Nonunion	Union
Number of mines	635	1,026
Employee-hours (millions)	62.5	524.1
Fatalities	33	168
Permanent disabilities	45	447
Intermediate injuries	1,336	13,128
Disabling injuries	2,369	33,279
Fatality rate(R_1)	0.11 (.02)	0.06 (.01)
Permanent disability rate (R_2)	0.14 (.02)	0.17 (.01)
Intermediate injury rate (R_{INT})	4.3 (.1)	5.0 (.1)
Disabling injury rate (R_D)	7.6 (.2)	12.7 (.1)

NOTE: Rates are average number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors.

ciated with fatality rates, we compared the fatality rates of union and nonunion mines within each category of mine size. The results, presented in Table 19, are very illuminating. Within each mine size category, the differences between union and nonunion fatality rates are not significantly different. The larger overall fatality rate for nonunion mines is explainable by the fact that the majority of nonunion employee-hours are in small mines, where the risk of a fatality is greater, whereas the majority of union employee-hours are in mines employing over 250 persons. Once size differences are accounted for, there are no differences in the fatality rates of union and nonunion mines.

Nearly all the mines with unknown union status are small and, in our opinion, likely to be nonunion. Accordingly, we recomputed the nonunion injury rates in Tables 18 and 19, classifying these mines of unknown status as nonunion. The results were not changed materially.

TABLE 19 Fatality Rates by Union Status and Mine Size for 1978-80

	Mine Size				
	1-50	51-150	151-250	Over 250	Total
Nonunion					
No. of mines	564	61	9	1	635
Employee-hours (millions)	26.7	25.9	9.0	0.9	62.5
Fatality rate (R_1)	0.14 (.03)	0.08 (.02)	0.09 (.04)	0.0	0.11 (.02)
Union					
No. of mines	563	221	107	135	1,026
Employee-hours (millions)	38.9	92.7	100.1	292.3	524.1
Fatality rate (R_1)	0.14 (.03)	0.08 (.01)	0.07 (.01)	0.05 (.01)	0.06 (.01)

NOTE: Rates are average number of fatalities per 200,000 employee-hours. Numbers in parentheses are estimated standard errors.

Productivity

Table 20 gives injury rates for mines grouped by productivity category, which is defined for each mine by the average tons of coal produced per employee-hour of labor. No association is evident between productivity and R_1 or R_2. There is no obvious explanation for the low fatality rate (0.03) among mines with productivity between 1.25 and 1.5. Examination of the analogous MSHA data for the period 1975-77 reveals no similar pattern or any other trend between R_1 and productivity.

Table 20 does indicate a negative overall association between productivity and R_D. That is, mines in the higher productivity categories tend also to have lower disabling injury rates. Since productivity is known to be related to characteristics such as mine size and seam height, we reexamined the association between productivity and R_D within the levels of other mine characteristics and also in a regression model. In these adjusted analyses the association between R_D and productivity, while generally negative, was much less apparent. For example, depending on which other mine characteristics were included in our regression model, the estimated decreases in R_D between the smallest and largest productivity categories varied between 1 percent and 16 percent. Because of the small magnitude of these differences, the conclusion we draw from these data is that the (cross-sectional) association between productivity and disabling injury rates, while perhaps slightly negative, is sufficiently weak to be disregarded as an important factor in explaining differences between injury rates in mines. This contradicts a belief held by some of a positive association between productivity and injury rates (that is, a belief that the more productive mines tend to have higher injury rates).*

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*A recent study by the General Accounting Office (Low Productivity in American Coal Mining: Causes and Cures, 1981) concludes that a cause-effect tradeoff exists between productivity and safety. Such a conclusion cannot, in our opinion, be legitimately based on a cross-sectional analysis, such as they performed. Rather, this type of question is better addressed by a longitudinal analysis, where changes in productivity over time for a given mine are correlated to corresponding changes in injury rates and mine characteristics.

TABLE 20 Injury Rates by Productivity for 1978-80 (unadjusted)

	Productivity (tons/employee-hour)				
	Under 0.75	0.75-1	1-1.25	1.25-1.5	Over 1.5
Employee-hours (millions)	86.9	122.3	134.0	97.9	193.3
Fatalities	30	47	49	13	97
Permanent disabilities	75	118	109	70	171
Disabling injuries	6,378	7,683	8,254	5,663	10,124
Fatality rate (R_1)	0.07 (.01)	0.08 (.01)	0.07 (.01)	0.03 (.01)	0.10 (.01)
Permanent disability rate (R_2)	0.17 (.02)	0.19 (.02)	0.16 (.02)	0.14 (.02)	.18 (.01)
Intermediate injury rate (R_{INT})	5.9	5.0	4.9	4.6	4.8
Disabling injury rate (R_D)	14.7	12.6	12.3	11.6	10.5

NOTE: Rates are average number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors. Estimated standard errors of R_{INT} and R_D are all less than .2.

Geographical Location by State

Table 21 gives the injury rates for seven states with at least 20 million employee-hours over the three-year period 1978-80. Note that the fatality rate for Virginia (0.13) is considerably higher than those for the other six states, which have a combined rate of 0.07. Part of this difference can be explained by mine size. In Virginia 36 percent of the employee-hours are from mines with 50 or fewer employees, and we have seen that small mines tend to have higher fatality rates than do larger mines. For all other states only 14 percent of employee-hours correspond to small mines. If the fatality rate for Virginia is adjusted to reflect a mine size distribution comparable with the rest of the industry, it drops to 0.10, which is still larger than that for the other states. Thus, while a part of Virginia's higher fatality rate can be explained by a substantial number of small mines, this state still has the highest fatality rate after adjustment for mine size. Our regression analyses lead to the same results, namely, that Virginia has the largest fatality rate among the seven large underground coal mining states after adjustment for other mine characteristics. Furthermore, Virginia's fatality rate for the six-year period 1975-80 was also the largest among all seven states.

The disabling injury rate for Kentucky (6.8) is substantially smaller than those for the other states, which have a combined rate of 13.7. This difference is due in part, but not entirely, to differences between the distributions of companies across the states and will be discussed further in a subsequent section.

Age of Miner

The MSHA accident/injury/illness report provides detailed information on the age and experience of each person who is the victim of a disabling injury. To analyze the correlation between age and injury rates, however, it is necessary also to know the age information for the entire workforce in a mine. Because this information is not collected by MSHA, we carried out a survey of the 19 largest coal companies, asking for the company-wide age distribution of their underground employees for each of the years 1978-80. Fifteen companies responded to the survey, accounting for 45 percent of the employee-hours for the entire underground coal mining industry between 1978-80.

TABLE 21 Injury Rates by State for 1978-80 (includes only those states with at least 20 million employee-hours)

	Alabama	Illinois	Kentucky	Ohio	Pennsylvania	Virginia	West Virginia
Employee-hours (millions)	27.3	57.4	111.5	37.6	105.2	54.6	198.9
Fatalities	12	18	42	7	32	35	62
Permanent disabilities	25	46	76	31	108	47	156
Intermediate injuries	704	1,434	1,929	1,123	2,731	1,796	4,864
Disabling injuries	1,554	3,340	3,818	3,200	7,870	3,742	12,097
Fatality rate (R_1)	0.09	0.06	0.08	0.04	0.06	0.13	0.06
Permanent disability rate (R_2)	0.18 (.04)	0.16 (.02)	0.14 (.02)	0.16 (.03)	0.21 (.02)	0.17 (.02)	0.16 (.01)
Intermediate injury rate (R_{INT})	5.2	5.0	3.5	6.0	5.2	6.6	4.9
Disabling injury rate (R_D)	11.3	11.6	6.8	17.0	15.0	13.7	12.2

NOTE: Rates are average number of injuries per 200,000 employee-hours. Standard errors of R_1 are about .02. Standard errors of R_2 are given in parentheses. Estimated standard errors of R_{INT} and R_D are all less than .3.

Table 22 gives injury rates by age category. There is no evidence of an age trend with respect to fatality rates (R_1) or permanent disability injury rates (R_2). However, there is a very marked correlation between age and disabling injury rates (R_D). Miners between the ages of 18 and 24 have an injury rate nearly twice that of miners 25 to 34, who have a rate about 25 percent higher than miners 35 to 44, who in turn have a rate over 40 percent higher than miners who are at least 45 years of age. Hence a young miner (18-24 years old) is about three times more likely to be injured than is a miner 45 years of age or older, and about twice as likely to be injured than is a miner 25-44. This relationship is evident for both intermediate (R_{INT}) and nonintermediate (R_D - R_{INT}) injury rates and was consistent across the 15 companies that provided us with age data, as well as for each of the years 1978, 1979, and 1980. Furthermore, the strong association between age and R_D was apparent for each of the major categories of accident types that cause injuries.

The magnitude of the injury rate differences across age groups can be appreciated when expressed in terms of numbers of accidents. For example, if the disabling injury rate for 18- to 24-year-old miners were reduced to that of all miners over 24, the 3,541 disabling injuries that occurred in this youngest age category would drop to 1,519, a decrease of over 2,000 injuries. Similarly, if miners between 25 and 44 had the same injury rate as those 45 and over, their 9,270 injuries (6,432 + 2,838) would decrease by nearly 3,000 injuries.

One possible explanation for the strong association between age and disabling injury rate has to do with the way we used the age distribution data collected from companies. It was assumed, for example, that if 15 percent of a company's underground employees were 18-24, then 15 percent of the total employee-hours they reported to MSHA were accounted for by workers between 18 and 24. The only indication we are aware of that could make this assumption inaccurate is that absenteeism rates tend to be greater among younger workers.* If this were the case, our calculations would overestimate the employee-hours in younger age categories and underestimate those in older age categories. However, this would mean that the asso-

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*See General Accounting Office (1981) Low Productivity in American Coal Mining: Causes and Cures, U.S. Government Printing Office, Washington, D.C.

TABLE 22 Injury Rates by Age for 1978-80 (from 15 companies)

	Age Category 18-24	25-34	35-44	Over 45
Employee-hours (millions)	34.9	112.3	81.9	73.2
Fatalities	8	29	23	24
Permanent disabilities	30	77	38	57
Disabling injuries	3,541	6,432	2,838	2,367
Fatality rate (R_1)	0.05 (.02)	0.05 (.01)	0.07 (.02)	0.07 (.01)
Permanent disability rate (R_2)	0.17 (.03)	0.14 (.02)	0.12 (.02)	0.16 (.02)
Intermediate injury rate (R_{INT})	7.8	4.4	3.7	2.7
(R_D - R_{INT})	12.5	7.1	5.5	3.8
Disabling injury rate (R_D)	20.3 (.3)	11.5	9.2	6.5

NOTE: Numbers in parentheses are estimated standard errors. Estimated standard errors of all other rates are less than .2.

ciation between age and disabling injury rate was even stronger than depicted in Table 22.

It is plausible that some portion of the observed association between age and disabling injury rates may be due to job experience and job type. That is, if miners with relatively little experience at a job are at greater risk for an injury than more experienced miners, then a correlation between age and job experience would induce an artificial association between age and disabling injury rates. Or it could be that the observed association between age and R_D has little to do with age per se but is actually due to younger miners having the more dangerous jobs. Our mine visits as well as the consistency of the association between age and R_D across accident types suggest that little of this association is explained by job type. However, it does seem plausible that a substantial portion of the association could be explained by job experience.*

*A comprehensive analysis of fatalities by T. Barry and Associates, Industrial Engineering Study of the Hazard

Unfortunately, an assessment of the relative importance of age (or overall mining experience) and experience at a particular job with respect to the risk of disabling injuries would require information about the joint age/job experience distribution of the entire workforce in a mine. This information does not, to our knowledge, exist on any large-scale basis; nor are we aware of any other studies that have examined this issue.

Other Mine Characteristics

There are several other mine characteristics that we would have liked to include in our analyses of injury rates but could not because the necessary data were unavailable to us. One of these is technology, specifically the relative safety of conventional, continuous, and longwall mining. Although longwall mining is used extensively in Europe, it accounts for less than 10 percent of the coal mined in the United States, and hence could not have a substantial impact on differences in injury rates between mines. Several comparisons made between continuous and conventional mining do not demonstrate any marked differences between their injury rates.* With respect to geological factors other than seam thickness, gassiness and roof conditions

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Associated with Underground Coal Mine Production (U.S. Bureau of Mines, 1971), concludes that job experience is of prime importance in the risk of fatal injuries. As pointed out by the authors, however, these findings must be regarded with some reservation because they were not based on normalized data. The study does include a normalized assessment of age and fatality rates and finds no clear association, which conforms to our findings about age and R_1. The Barry analyses do not consider nonfatal disabling injuries. Similar remarks apply to Sinha, A. K., Stefano, R., and Ramani, R. V. (1974) "Analyzing Mine Electrical Power Accidents," Transactions of the SME, AIME 256:148-152.

*See Boden, L. I. (1977) "Coal Mine Accidents and Government Enforcement of Safety Regulations," Doctoral Thesis, Harvard University; also, Schlick, D. P., Peluso, R. G., and Thirumalai, K. (1976) "U.S. Coal Mining Accidents and Seam Thickness," Symposium on Thick Seam Mining by Underground Methods, Australian IMM Central Queensland Branch.

are two obvious characteristics that might be related to injury rates. However, we know of no data or studies that assess their correlation to injuries. It would also have been desirable to determine the effects of degree of federal or state enforcement of regulations on safety. Such analyses have been attempted by others,* but the data are extremely difficult to interpret because frequency of inspection is related to reported injuries. Finally, were absenteeism data available, it would have been possible to determine whether mines with greater absentee rates have higher injury rates, and whether injury proneness is changed after a period of absence.

COMPANY COMPARISONS

This section investigates the association between injury rates and the companies that control underground coal mines. Although controlling company as a potential correlate of injury rate is similar to the factors considered previously, we felt this factor deserved closer scrutiny since it is here that possible biases due to reporting practices would seem to be potentially more serious.

The data reveal substantial differences in injury rates between companies that cannot be explained by statistical fluctuations, by differences in reporting practices, or by mine or miner characteristics such as age, mine size, seam thickness, etc. Case studies and analyses of injury rates for different time intervals further support the indication that the differences in injury rates between companies are due to the companies themselves.

Company Injury Rates, Mine Variations Within Companies, and Consistency in Injury Reporting

In their 1980 report the President's Commission on Coal focused on the 20 companies that as of 1978 were the largest bituminous coal producers in the United States. One of these 20 companies went out of business after 1978. Because these companies account for about 80 percent of the underground coal produced, and because using all coal companies would entail the inclusion of many very small companies, we restricted attention to the 19 remaining companies in this part of our analysis.

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*See L. I. Boden, ibid., and references therein.

Table 23 gives the total number of employee-hours, disabling injuries, and fatalities and permanent disabilities, as well as the corresponding injury rates, for the 19 companies. The data are for the period 1978-80, and the companies are listed in order of their intermediate injury rates (R_{INT}).

Note the large differences between companies. For example, there is a nearly fivefold difference between the disabling injury rates at Old Ben or Mapco and those at North American or Westmoreland. Only a negligible amount of the differences in the disabling injury rates (R_D) and in the intermediate injury rates (R_{INT}) between the companies can be accounted for by chance fluctuations: The estimated standard error of each R_D in the table is less than 1.0, and that of each R_{INT} is less than 0.5 (with most standard errors being considerably less than 1.0 and 0.5, respectively).

The impact of these rate differences can be appreciated when translated into actual numbers of injuries. For example, if the four companies at the bottom of Table 23 had intermediate injury rates equal to the combined average of the other 15 companies, the 2,171 intermediate injuries in these four companies would have been 1,147, a reduction of nearly half. More generally, if the bottom 12 companies in Table 23 (which account for about half of the total employee-hours represented) had disabling injury rates equal to those of the remaining 7 companies, the number of disabling injuries in those 12 companies would have been 7,399 rather than 15,401; i.e., more than half of the disabling injuries in the bottom 12 companies would not have occurred.

Figure 15 plots for each company the rate of intermediate injuries (R_{INT}) versus the rate of remaining injuries ($R_D - R_{INT}$). Recall that $R_D - R_{INT}$ represents degree 3-5 injuries resulting from material handling, slipping/bumping, and other accidents, which were felt by the Committee to be more susceptible to reporting inconsistencies than intermediate-type injuries. The strong correlation indicates that companies with higher rates of degree 3-5 injuries from material handling and slipping/bumping also have higher rates of intermediate injuries. An association between R_{INT} and $R_D - R_{INT}$ was also seen previously (Figure 14) for individual mines grouped on the basis of their R_{INT} values. That Figure 15 also demonstrates this association further suggests that differences between companies in reporting patterns are relatively small compared with the

TABLE 23 Injury Rates by Company for 1978-80

	Fatalities and Permanent Disabilities	Fatality and Permanent Disability Rate	Disabling Injuries	Intermediate Injuries	Employee-Hours (millions)	Disabling Injury Rate (R_D)	Intermediate Injury Rate (R_{INT})
Old Ben	12	.11 (.03)	286	173	12.71	4.5	2.7
Bethlehem	46	.16 (.02)	1,050	397	27.46	7.6	2.9
Island Creek	63	.18 (.02)	951	462	31.10	6.1	3.0
Consolidation	116	.16 (.02)	2,791	1,001	67.25	8.3	3.0
Mapco	9	.25 (.08)	110	79	4.99	4.4	3.2
U.S. Steel	49	.14 (.02)	1,391	621	34.69	8.0	3.6
Alabama By-Product	22	.23 (.05)	457	194	10.00	9.1	3.9
Eastern Associated	38	.16 (.03)	1,576	490	21.03	15.0	4.7
Peabody	72	.20 (.02)	2,105	821	34.13	12.3	4.8
Jones and Laughlin	26	.23 (.05)	747	308	12.63	11.8	4.9
Rochester and Pittsburgh	18	.19 (.04)	678	266	10.39	13.0	5.1
Amer. Electric Power	26	.19 (.04)	1,230	400	15.66	15.7	5.1
Pittston	72	.22 (.03)	1,727	781	28.96	11.9	5.4
Zeigler	13	.18 (.05)	531	217	7.01	15.2	6.2
Republic	26	.27 (.05)	1,005	368	10.76	18.7	6.8
Freeman United	22	.26 (.06)	713	315	9.23	15.4	6.8
North American	44	.17 (.03)	2,795	958	25.64	21.8	7.5
Westmoreland	42	.26 (.04)	1,653	602	15.67	21.1	7.7
Valley Camp	15	.22 (.06)	641	296	6.80	18.9	8.7
Total or average	731	.18 (.01)	22,437	8,749	386.11	11.6	4.5

NOTE: Rates are average number of injuries per 200,000 employee-hours. Fatalities and permanent disability injuries (R_{12}) are based on the period 1975-80. All other data for the period are for 1978-80. Companies are listed in order of their intermediate injury rates (R_{INT}). Estimated standard errors are in parentheses. Estimated standard errors of R_{INT} and R_D are less than 0.5 and 1.0, respectively.

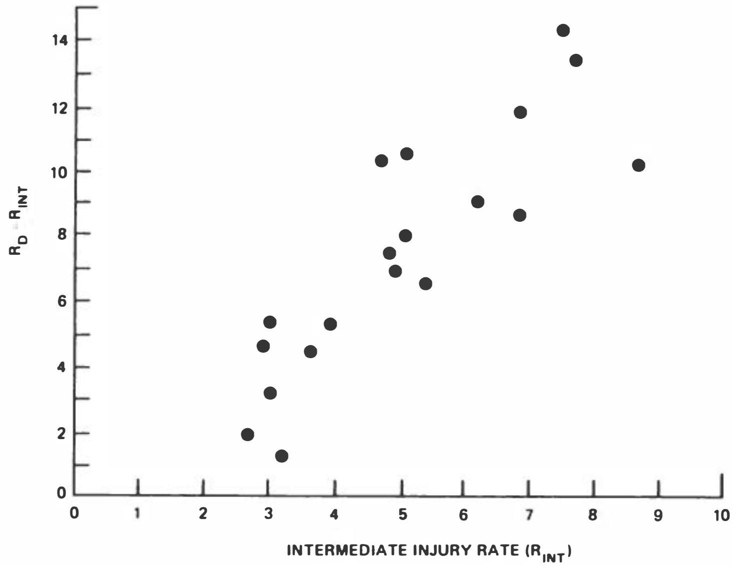

FIGURE 15 Scatter plot of nonintermediate disabling injury rates ($R_D - R_{INT}$) and intermediate injury rates (R_{INT}) for 19 companies for 1978-80.

large differences between companies in injury rates. That is, while small differences in the disabling injury rates between two companies might be explained by differences in reporting practices, large differences cannot be so attributed and reflect real differences in injury rates.

Figure 16 gives a scatter plot of the intermediate injury rates (R_{INT}) and fatality and permanent disability rates (R_{12}) for each company. The statistical fluctuation associated with each R_{INT} is negligible, but it is not negligible for R_{12}. Accordingly, the diameter of the circle used for each company is based on the estimated standard error associated with the respective R_{12}. Companies for which R_{12} can be estimated more precisely are represented with larger circles. Note that companies with larger intermediate injury rates also have larger rates of fatalities and permanent disabilities. This trend was assessed by linearly regressing R_{12} onto R_{INT} using a Poisson regression model, which yielded $R_{12} = 0.12 + 0.0143R_{INT}$, with the estimated slope being significantly greater than zero ($P = .001$). This trend is consistent

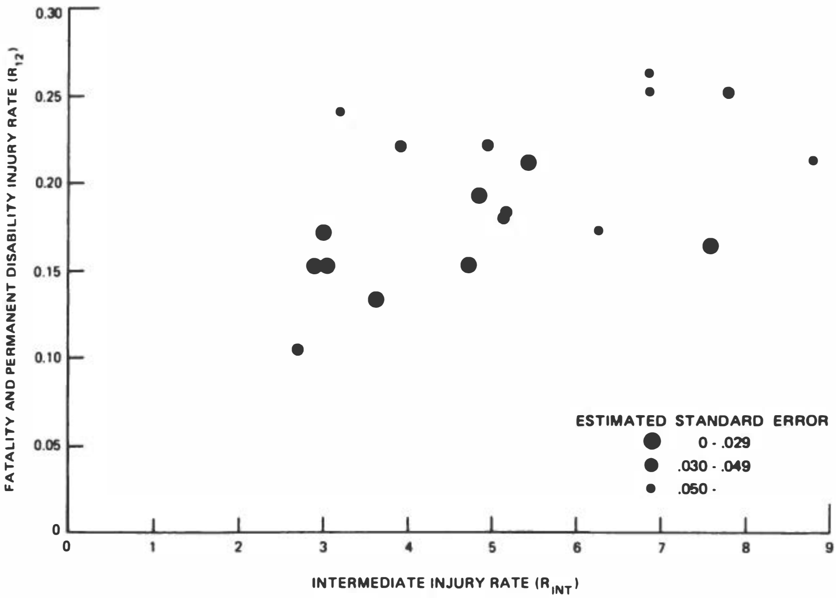

FIGURE 16 Scatter plot of intermediate injury rates (R_{INT}) versus fatality and permanent disability injury rates (R_{12}) by company. R_{12} is based on 1975-80 data; R_{INT} is based on 1978-80 data.

with that seen in Figure 14 for individual mines grouped by R_{INT} values. That it is also apparent for mines grouped by company demonstrates that companies with high injury rates are also at greater risk for fatalities and permanent disabilities.

We next decomposed each company's disabling injury rate (R_D) according to the contribution from each type of accident. The results are presented in Table 24, in which companies are listed in order of their overall disabling injury rates. For example, North American had an average of 21.8 injuries per year for every 100 miners. Of these, 1.8 (8 percent) resulted from roof/side falls, 2.7 (12 percent) were from haulage accidents, 2.5 (11 percent) were from mishaps with machinery, 4.1 (19 percent) involved material handling, and 2.0 (14 percent) were due to slipping/bumping. Note from the table that companies having large injury rates corresponding to one type of accident (e.g., material handling) tend also to have large injury rates for other types of accidents (e.g., roof/side

TABLE 24 Company Injury Rates as a Function of Accident-Causing Injury for 1978-80

Company (R_D)	Roof/Side Falls	Haulage	Machinery	Electrical/ Explosive	Material Handling	Slipping/ Bumping	Other	Overall Disabling Injury Rate
Mapco	1.0	1.0	.9	.1	.8	.5	0	4.4
Old Ben	.8	.6	1.1	.2	.8	1.0	0	4.5
Island Creek	.8	.8	1.0	.2	2.2	1.0	0	6.1
Bethlehem	.7	1.1	.9	.2	2.8	1.9	.1	7.6
U.S. Steel	.8	1.3	1.2	.2	1.9	2.5	.1	8.0
Consolidation	.7	1.1	.9	.2	2.9	2.4	.1	8.3
Alabama By-Product	.8	1.9	.8	.3	2.4	1.8	1.1	9.1
Jones and Laughlin	1.3	1.4	1.5	.5	4.2	2.9	.1	11.8
Pittston	1.1	2.0	1.9	.3	4.0	2.5	.1	11.9
Peabody	.8	2.0	1.5	.5	4.6	2.9	.1	12.3
Rochester and Pittsburgh	1.4	1.8	1.8	.2	4.6	3.2	.2	13.0
Eastern Associated	1.1	1.6	1.5	.4	6.4	3.8	.2	15.0
Zeigler	1.0	2.3	2.2	.7	5.0	3.9	.1	15.2
Freeman United	1.8	2.1	2.3	.5	4.1	4.6	.1	15.4
Amer. Electric Power	1.0	2.1	1.7	.3	5.8	4.7	.2	15.7
Republic	1.6	2.3	2.3	.5	6.5	5.2	.3	18.7
Valley Camp	2.5	2.9	2.6	.6	5.8	4.3	.2	18.9
Westmoreland	1.7	2.7	2.8	.5	8.8	4.3	.5	21.1
North American	1.8	2.7	2.5	.4	7.7	6.4	.2	21.8
Average (19 companies)	1.0	1.6	1.5	.3	4.1	3.0	.2	11.6

NOTE: Rates are average number of injuries per 200,000 employee-hours. Estimated standard errors of overall disabling injury rates (R_D) are all less than 1.

falls). Had companies with larger overall injury rates only had higher rates for material handling and slipping/bumping injuries, it would suggest that the large overall company differences might be due in large part to reporting differences. However, the table clearly indicates that companies with the poorer injury rates tend to have proportionally more accidents of all types than do other companies. This consistency over the type of accident further suggests that a lack of comparability in reporting accounts for only a small amount of the differences between company injury rates; most of these differences represent true differences in the rates of injuries.

Figure 17 describes the variation in disabling injury rates of the mines within each company. The companies are ordered (left to right) on the basis of their intermediate injury rates. For each company the box identifies the 25th and 75th percentiles of the disabling injury rates of the mines within that company, and the horizontal bar indicates the median injury rate of the mines. For example, 25 percent of Consolidation Coal Company's mines have disabling injury rates below 2.0, and 25 percent have rates above 9.7; the median injury rate among Consol's mines is 6.8, which means that about half of Consol's mines had injury rates above 6.8 and about half had rates below 6.8.

If mines within companies were no more alike than mines between companies, the vertical bars would tend to be alike, both in their vertical height and displacement. The large differences between the bars, however, indicates this is not the case. In companies on the left, most mines have injury rates below the industry average, while just the opposite is true for the companies on the right. To illustrate, only one of Westmoreland's 31 mines has an injury rate below 11.0, and this mine was quite small (13,386 employee-hours) and owned only in 1978. In contrast, none of Bethlehem's 30 mines had an injury rate above 16.0, and all but 5 had injury rates below 10.0.

Company Variation Explainable by Other Correlates of Injury Rate

It is clear that there are real and large differences in the disabling and intermediate injury rates of the 19 companies, differences that cannot be explained by statistical fluctuation or reporting practices. One possibility, of course, is that the observed differences

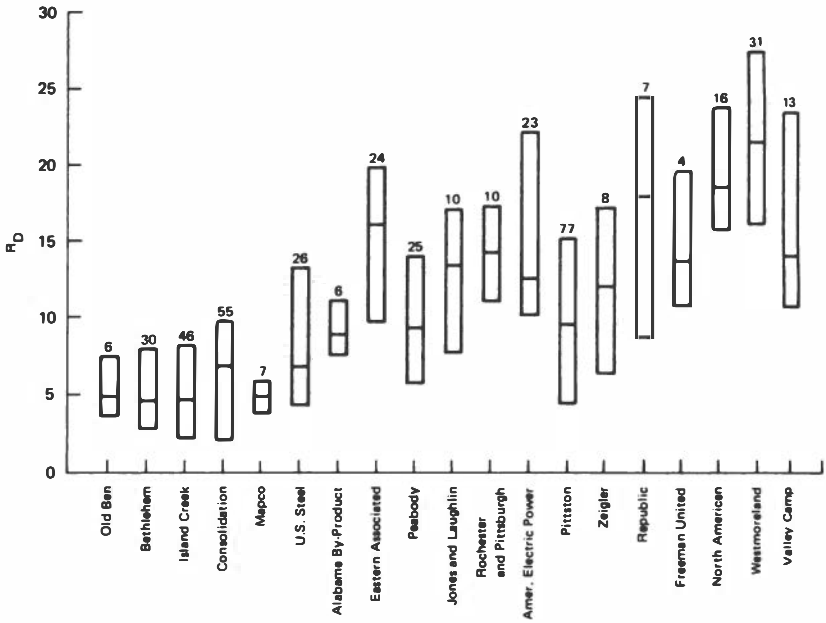

FIGURE 17 Disabling injury rates for mines within companies, 1978-80. The top and bottom of each box denote the 75th and 25th percentiles, and the bar in the interior of each box denotes the median of mine disabling injury rates. Numbers above bars indicate the number of mines in each company.

in company injury rates are due to imbalances between companies in geology, geography, technology, or demography. To assess this possibility, we first used multiple regression methods to see whether any potential substantial part of the observed differences in company injury rates could be explained by size, seam thickness, union status, productivity, or state (location of mines). The adjustment of company rates by these characteristics had a negligible effect. To illustrate the combined association of state and company with R_D, Table 25 gives disabling injury rates for the three states having the greatest number of employee-hours and the companies having mines in at least two of these states. The companies are listed in order of their overall disabling injury rates.

Note first that companies with larger overall injury rates tend to have the larger rates within each state.

TABLE 25 Disabling Injury Rates by Company and State for 1978-80

Company	Kentucky	West Virginia	Pennsylvania	Company Rate (three states)
Island Creek	3.3	4.7	4.8	3.7
Bethlehem	2.5	3.5	10.2	7.6
U.S. Steel	2.8	4.8	12.5	7.8
Consolidated		7.1	12.1	8.1
Jones and Laughlin		24.0	9.2	11.7
Pittston	3.6	11.5		9.8
Republic	18.6 (2.2)	24.4	21.7 (1.5)	22.1
State rate (for companies shown)	3.6	7.7	11.8	8.6

NOTE: Rates are average number of injuries per 200,000 employee-hours. Numbers in parentheses are estimated standard errors; all other rates have estimated standard errors less than 1.0.

This shows that the overall differences in injury rates between these companies are not due to differences in the geographical locations of their mines.

The table also suggests that the differences between states cannot be fully explained by the difference between companies. Within companies, Kentucky's rates tend to be lower than West Virginia's, and these in turn tend to be lower than Pennsylvania's. These state differences might reflect differences in geology, or, what is more likely, they might reflect differences in state laws that affect training, education, and liability compensation.

Consider next whether the observed company differences in disabling injury rates can be explained by age differences.* Since younger miners have substantially higher injury rates than do older miners, companies with proportionally more young miners would tend to have higher overall injury rates than would companies with fewer young miners. To see whether this could explain any substantial portion of the differences between company injury rates, we compared the age distributions of the 15 companies that responded to our survey and found that the companies with

*Age could not be included into our regression analyses because it was only available on a company-wide basis and not for each individual mine within a company.

the higher disabling injury rates did not have an excess of young miners. We then computed adjusted disabling injury rates for each company, standardized to the combined age distribution of the entire sample (12 percent, 40 percent, 22 percent, and 26 percent in the 18-24, 25-34, 35-44, and 45+ categories, respectively). The adjusted disabling injury rates, which correct for age-distribution differences between the companies, did not differ materially from the unadjusted rates: Only 3 of the 15 adjusted company rates differed by more than 1.5 from their unadjusted counterparts, and these three differences were less than 3. Thus, despite the strong correlation between age and disabling injury rates, the age distributions across the 15 companies we examined were sufficiently similar that no appreciable amount of the observed company differences in injury rates could be explained by age.

Another important fact that emerged from our analysis of age and company is that companies differ most markedly in their injury rates for miners in the 18- to 24-year-old age category. This is illustrated in Figure 18, which gives the age-specific disabling injury rates for the first five companies that responded to our survey. Within each company (represented by a solid line) there is a steady decline in injury rates with age. This reflects the association between R_D and age for that company. The vertical distances between companies indicate how their injury rates differ within each age category. The most striking aspect of the figure is the big difference in injury rates for the 18- to 24-year-old category. The injury rates for 18- to 24-year-old miners in companies A and B are about 50, compared with rates of about 15 in companies D and E. The injury rates for company C are comparable with those of companies D and E among miners 25 and over, but substantially higher for miners 18-24. One explanation for company C differing from companies D and E only among miners 18-24 years old could be that their training of young miners is less effective. This could be due to differences in state training requirements in the states where these companies mine, or to the quality of the companies' specific training programs. Since we only had the age distribution of miners on a company-wide basis, it was not possible to determine whether there are state differences in injury rates for miners 18-24 after adjustment for company. However, it seems to us more plausible that the differences between companies C, D, and E with respect to injury rates of young miners are due to the quality of their training programs.

Finally, we considered the plausibility that a sizable portion of the observed differences in company injury

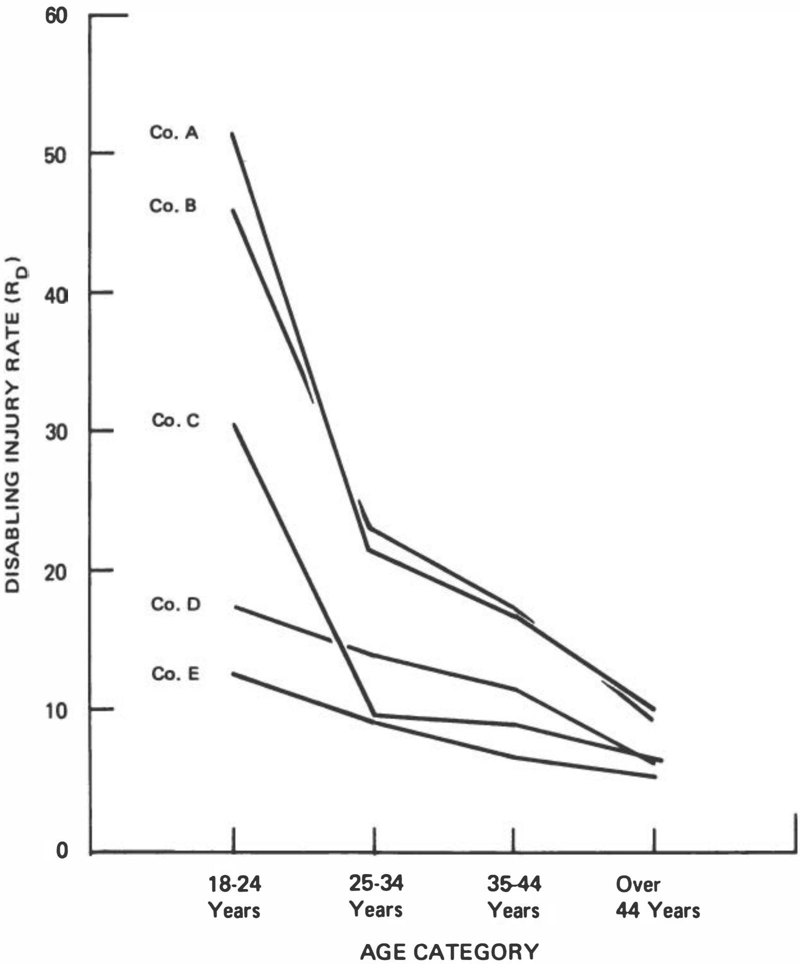

FIGURE 18 Disabling injury rate (R_D) by age category for five companies, based on the period 1978-80.

rates could be explained by some mine characteristics for which we do not have data. For this to occur, two conditions must hold.* First, the characteristic in question must have an extremely strong correlation with disabling

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*These conditions can be stated quantitatively; see, for example, Schlesselman, J. J. (1978) "Assessing Effects of Confounding Variables," American Journal of Epidemiology 108:3-8.

injury rates--e.g., at least as strong as the association between age and injury rates. Second, the characteristic must be extremely imbalanced across companies. For example, age, while strongly correlated with R_D, had a distribution that did not differ markedly between companies, and as a result company injury rates were hardly altered after adjustment for age. From the references and results cited in "Other Mine Characteristics" above, it is clear that mining method and measures of enforcement could not possibly explain a large part of the differences between company injury rates. Nor, for that matter, does it appear even remotely possible that some other geological, demographic, or technological factor could at the same time be sufficiently strongly correlated with R_D and sufficiently imbalanced across companies to explain any sizable portion of the large company differences in disabling injury rates.

To summarize, the results of this section indicate that the large differences in injury rates between companies cannot be explained to any substantial degree by reporting practices or by any of the mine characteristics that we analyzed. Nor does it appear plausible that they could be accounted for by mine characteristics that we could not measure directly. Rather, it appears that these differences are due to factors internal to the companies.

Time Trends

Company injury rates were examined on a quarterly, semiannual, and annual basis over the three-year period 1978-80. Table 26 gives for each half year the disabling injury rate and number of disabling injuries (in parentheses) for the 19 companies under study.

The first 10 companies listed have injury rates that were relatively steady over this period. This designation is somewhat liberal, due to the many factors (age, mine acquisition, etc.) that can change injury rates. For example, the decrease in Westmoreland's injury rate in 1979 and 1980 can be explained by a shift in the age distribution of their miners. It is quite possible, of course, that some of these companies are experiencing gradual trends upward or downward.

Five companies exhibit marked trends: Eastern Associated, which will be discussed in greater detail in the next section, has shown a steady and large drop in injury rates. North American, Pittston, American Electric Power,

TABLE 26 Semiannual Disabling Injury Rates and Total Disabling Injuries (in parentheses) by Company for 1978-80

Company	1978		1979		1980	
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
Alabama By-Product	5.2 (29)	8.5 (68)	5.9 (54)	10.7 (96)	12.4 (117)	10.5 (93)
Bethlehem	6.8 (107)	8.4 (214)	8.9 (248)	7.8 (203)	5.9 (141)	7.6 (137)
Consolidated	8.2 (364)	9.0 (555)	8.4 (561)	7.8 (458)	8.0 (436)	8.3 (417)
Island Creek	5.4 (114)	5.0 (144)	6.3 (197)	6.6 (178)	6.3 (164)	7.1 (154)
Mapco	5.7 (15)	3.8 (12)	5.8 (25)	3.0 (14)	4.4 (23)	4.3 (21)
Old Ben	8.4 (48)	6.6 (71)	5.1 (61)	2.4 (27)	3.6 (49)	3.0 (30)
Peabody	8.5 (157)	10.1 (344)	10.1 (340)	16.1 (471)	14.4 (437)	14.2 (356)
Rochester and Pittsburgh	11.3 (61)	13.2 (119)	13.1 (127)	14.8 (131)	13.7 (135)	11.5 (105)
U.S. Steel	10.2 (210)	11.1 (346)	7.2 (247)	6.0 (185)	7.3 (229)	6.9 (174)
Westmoreland	19.3 (191)	24.8 (373)	22.8 (330)	21.2 (278)	19.6 (262)	17.6 (219)
Eastern Associated	14.2 (216)	22.9 (469)	17.2 (341)	15.7 (265)	9.7 (160)	7.6 (125)
North American	12.0 (198)	13.1 (306)	17.9 (438)	30.1 (633)	28.7 (627)	28.2 (593)
Pittston	6.8 (139)	8.2 (199)	9.7 (258)	10.9 (238)	15.6 (394)	18.9 (499)
Amer. Electric Power	8.8 (75)	10.8 (159)	18.4 (262)	18.1 (215)	18.3 (274)	17.6 (245)
Republic	14.9 (81)	13.5 (123)	19.7 (192)	21.3 (195)	23.4 (241)	17.2 (173)
Freeman United	9.3 (47)	9.3 (82)	10.9 (102)	22.6 (191)	19.4 (140)	20.8 (151)
Zeigler	20.4 (91)	19.0 (135)	19.1 (114)	19.1 (109)	7.2 (46)	6.7 (36)
Jones and Laughlin	5.0 (27)	7.4 (48)	18.8 (273)	13.1 (163)	11.9 (156)	7.1 (80)
Valley Camp	9.0 (30	15.1 (98)	21.8 (149)	25.8 (151)	21.1 (126)	15.8 (87)

NOTE: Rates are average number of disabling injuries per 200,000 employee-hours.

and Republic have rates that are getting progressively higher and, with the possible exception of Republic, give no strong indication of reversing.

Two companies, Freeman United and Zeigler, show a single precipitous shift in injury rates that otherwise are steady. A closer examination of their data suggests that a good part of these shifts may be a reporting phenomenon.

The injury rates at Jones and Laughlin and at Valley Camp appear to increase and then decrease. This might signal a genuine improvement in safety at these companies, though the results must still be regarded as equivocal.

CASE STUDIES

One of the findings from the previous sections is that companies differ markedly in their ability to prevent injuries. In this section we focus on one company, Eastern Associated, whose reported injury rates have steadily and substantially declined during the three-year period 1978-80 and on two other companies, Old Ben and U.S. Steel, whose reported injury rates have consistently been much better than average. Our purpose in studying Eastern Associated is to document their reduction in injury rates in greater detail and to determine plausible causes for this improvement. The rationale for studying Old Ben and U.S. Steel in greater depth is somewhat different. Because these companies have been able to both achieve and maintain relatively low injury rates, we felt that their attitudes, policies, and programs concerning safety merited special attention.*

Eastern Associated Coal Corporation

Eastern Associated operates primarily in West Virginia. The company has 5,000 employees currently, operates 21 underground mines, and produced about 7 million tons of coal in 1980.

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*As indicated in the preceding section, Old Ben and U.S. Steel are not the only companies that have maintained good injury rates. We select them because we had more information about their organizational structure than we had for other companies.

Eastern Associated has shown an improving safety record since 1977. As can be seen from Table 27, their disabling injury rate has steadily decreased from 22.9 in the second half of 1978 to 7.6 in the second half of 1980.

To explore the extent of this apparent improvement, we examined trends in injury rates for each mine within Eastern, for each of the four age categories, and for each type of accident. The reduction in reported injury rates was consistent within each of these areas. Among the 21 mines under Eastern's control throughout 1978-80, 18 had lower injury rates in 1980 than they did in 1978, and two others had relatively stable rates over this period. Between 1979 and 1980, the years for which we had age data, injury rates within each of the four miner age categories declined. In addition, each of the major type-specific accident rates for the company tended to decline over the three-year period. Thus the reduction in reported injuries over this period is consistent throughout the company.

We considered the possibility that the decline in injury rates was a statistical artifact. The likelihood that a trend such as that observed could occur by chance is almost nil. Similarly, the decline was not caused by the acquisition of mines with low injury rates or by the selling or closing of mines with high injury rates. A third possible explanation is that the decline was purely a reporting phenomenon. For example, there may have been either a subconscious or deliberate change in the interpretation of CFR 50, causing a reduction in the number of injuries reported to MSHA. However, such a change would more likely lead to a precipitous drop in accident rates, not to the observed gradual decrease over a more prolonged period. It thus seems quite unlikely that the reduction in injury rates was a reporting phenomenon. This conclusion was also supported by a senior representative of the company, who knew of no changes in the reporting practices for injuries.

We next considered possible causes for the impressive improvement at Eastern Associated between 1978 and 1980. Geological changes, though they can and do occur, clearly could not explain the large and consistent reductions in injury rates. Another possible explanation for the reduction in injury rates was a shift in the age distribution of Eastern's workforce to one with fewer young employees. However, we were informed by Eastern's safety director that the workforce was relatively stable over this period. Furthermore, our analyses of Eastern's injury data by year revealed that the injury rates declined within each age category. A third possible cause for Eastern's improvement might have been a substantial change in technology. However, according to their safety director there were no systematic changes in machinery.

The major changes that did occur at Eastern, and which in our opinion were responsible for the reduction in injury rates, were in the company's commitment to and programs for safety. The company embarked on a complete reorganization of its safety operation. Control was taken from the local mine management and placed with company headquarters under the direction of a vice president, a director of safety, and three division inspectors. Each mine has a company mine inspector, sometimes with several assistants.

At Eastern all safety data are fed into a computer so that the safety director can track the accident record of every worker or supervisor, the number of accidents, the amount of lost time, and the nature of each accident. "In production," the safety director observed, "you know the score every day; in safety it takes a long time to know if you are doing well." The safety director believes that future gains in safety depend largely on behavior modification, but also on cooperation between the company, the union, and MSHA. "We do not need further regulation," he said. "Accidents now result from work habits and practices. We need programs generated by the company to motivate workers and elicit the cooperation of labor and MSHA." Training is regarded as an important part of the safety program. Eastern stresses continual job safety contacts between foremen and workers. The safety director feels that Eastern has a progressive program, that they have improved greatly, and that they will continue to improve.

Virtually everyone in the safety department has attended the MSHA academy at Beckley, West Virginia. They have also attended training programs conducted by the National Safety Council and by Virginia Polytechnic Institute.

Three of Eastern's mines have experimented with a bonus system that combines rewards for safety and productivity. Under this system a productivity bonus can be wiped out or doubled by a 100 percent increase or decrease in accident or violation rates. If the accident and violation rates change less drastically, the bonus is prorated accordingly. Bonuses of this kind were permitted by the 1978 UMWA-BCOA contract if the local UMWA union approves.

Other Eastern mines have a different kind of safety bonus based on a goal set by the mine superintendent in consultation with safety personnel and with management and union representatives.

There are two important lessons to be learned from the success that Eastern has had in reducing its injury rate. First, their success demonstrates that a company's commitment and programs for safety can have an enormous impact on injury rates. This supports our previous finding that the large differences between companies are due to the companies themselves. Second, Eastern's example demonstrates that real improvements in safety can be achieved in a reasonably short period of time. This suggests that other companies with poor safety records can also improve their injury rates substantially and in a short period of time, given a strong commitment to do so.

Old Ben Coal Company

A reduction in company injury rates from levels above the industry average to levels well below the average, as achieved by Eastern, is meritorious. However, perhaps an even greater accomplishment is to reduce injury rates and keep them low over a number of years. Old Ben attracted the Committee's attention not only because the company has one of the lowest accident rates in the industry but because it has been able to maintain and even improve its performance over the past three years. This low injury rate is fairly consistent over several categories and for each of its mines. Interviews with the vice president of operations and with the manager of corporate safety shed some light on this achievement.

The current manager of corporate safety was hired in 1978 to take charge of the company's safety program. He reports to the highest level of management for the operation of Old Ben's underground coal mines. The vice president of operations has let it be known throughout the company that he fully supports the safety manager in his efforts to achieve safety in Old Ben's mines.

The current manager of corporate safety has restructured the safety department. Safety engineers at the mines previously reported to mine management, but now report to the corporate manager. In the past, qualifications for safety personnel were not well defined, but now have been increased; for instance, all safety inspectors must have mine manager papers and prescribed training in safety engineering. Previously, a position in the safety department tended to be a transition or a dead end for a career; in contrast, safety inspectors now have a career within the department and are considered potential mine managers and superintendents. As a result of this restructuring, the safety department personnel has almost completely turned over since the new safety manager's arrival at Old Ben in 1978. The changes in the safety department mirror changes in top corporate management during recent years and no doubt have influenced Old Ben's declining injury rates between 1978 and 1980.

U.S. Steel Corporation

U.S. Steel is one of the largest producers of coal in the United States. It ranks fourth in production and operates 26 underground mines. U.S. Steel coal mines are captive mines because much of their coal output is used by the parent company, in this case to make steel.

U.S. Steel was ranked first with respect to injury incidence rates by the President's Commission on Coal in their listing of the 20 largest underground coal companies. This ranking was based on data for 18 months (January 1978–June 1979) and on degree 1-4 injuries only. Degree 5 injuries, those involving only restricted duty, were not included. At the time of the Coal Commission's survey, U.S. Steel was the largest user of restricted duty within the coal industry, believing it better for a worker's morale for him to be at work of any kind rather than at home. The exclusion of degree 5 injuries raised U.S. Steel's standing relative to other companies who made relatively little use of restricted duty. In our analyses, which included degree 5 injuries, U.S. Steel is not first, but still ranks as one of the safer companies. Moreover, as indicated in Table 26, U.S. Steel's injury rate has been improving over the last three years.

Two senior representatives of U.S. Steel, their chief inspector for coal mining, and a general superintendent met with the Committee and described their safety program. They were pleased to have been ranked first in the Coal Commission's report, but they realized that the report was based on degree 1-4 injuries only. In answer to the question "Why does U.S. Steel have a good safety program?" their chief inspector gave three reasons.

1. Their program is aimed at motivating individuals.

2. Every member of management is responsible for safety.
3. They do not mind repetition and are probably repetitive to a fault.

The general superintendent described the basic elements of U.S. Steel's safety program. The first of these is job safety analysis; it involves the development of safety procedures for doing every job in the mine. The procedures are developed through discussions between the workers and the foremen and by observing well-trained workers doing the job safely. Then the workers and the foremen are given basic training, using the procedures developed by the analyses.

The foreman's job is to observe each worker the first time he does the job and certify that he is doing it properly. Thereafter, the foremen must make a follow-up inspection twice every month for each worker. An employee safety record is kept for each mine worker. This record contains the foreman's observations of violations and unsafe acts by the worker and notes any injuries that befell the worker. A violation is any action that is contrary to the worker's training; violations should result in disciplinary action. An unsafe act is one not covered by safety procedures; unsafe acts should result in revisions of the procedures. The safety record moves with the worker from job to job and hence is independent of foremen.

For every accident the foreman must conduct an investigation and write a report. Each of these reports is reviewed by the mine superintendent. The daily record of accidents at each mine is reviewed by the district general superintendent. The general superintendent is responsible to the general manager for coal operations of U.S. Steel for the accidents in his district. Throughout this process the responsibility for safety resides in the line management of the company. Safety inspectors, safety engineers, and statisticians are staff to the line management.

With regard to the physical conditions in the mine and the equipment used, U.S. Steel's program rests on three principles: (1) designing for safety to standards developed by U.S. Steel, (2) extensively checking the equipment before use, and (3) repeatedly inspecting equipment throughout its lifetime. If there is concern about the safety record of any mine, a safety audit is conducted by general management and is reported to the general superintendent and the general manager for coal operations.

It was clear to the Committee that U.S. Steel's commitment to safety was strong, in part because it relied on line management for implementation. U.S. Steel was one of the first to use job safety analysis in the coal industry, and the methods of their safety program have been widely copied. Several major coal companies freely admit that they have patterned their safety programs after U.S. Steel's. Their attitude toward labor is characterized by toughness, but also by fairness. They put high value on training and competence. It is not surprising that U.S. Steel has been one of the leaders in coal mine safety over a long period of time.

APPENDIXES FOR CHAPTER 4

APPENDIX 4-A: MINE REPORTS SUBMITTED TO MSHA

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Mine Accident, Injury and Illness Report

U. S. Department of Labor
Mine Safety and Health Administration

Form Approved, OMB No. 044-R1665, Expires December 1982.

● Section A – Identification Data

MSHA ID Number | Contractor I.D. | Report Category: ☐ Metal/Nonmetal Mining ☐ Coal Mining | ☐ Check here if report pertains to contractor.

Mine Name | Company Name

● Section B – Complete for Each Reportable Accident Immediately Reported to MSHA

1. Accident Code (circle applicable code – see instructions) 01 – Death 02 – Serious Injury 03 – Entrapment 04 – Inundation 05 – Gas or Dust Ignition 06 – Mine Fire 07 – Explosives 08 – Roof Fall 09 – Outburst 10 – Impounding Dam 11 – Hoisting 12 – Offsite Injury

2. Name of Investigator

3. Date Investigation Started

Month	Day	Year

4. Steps Taken to Prevent Recurrence of Accident

● Section C – Complete for Each Reportable Accident, Injury or Illness

5. Circle the Codes Which Best Describe Where Accident/Injury/Illness Occurred (see instructions)

(a) Surface Location: 02 Surface at Underground Mine 30 Mill, Preparation Plant, etc. 03 Strip/Open Pit Mine 04 Surface Auger Operation 05 Culm Bank/Refuse Pile 06 Dredge Mining 12 Other Surface Mining 17 Independent Shops (with own MSHA ID) 99 Office Facilities

(b) Underground Location: 01 Vertical Shaft 02 Slope/Inclined Shaft 03 Face 04 Intersection 05 Underground Shop/Office 06 Other

(c) Underground Mining Method: 01 Longwall 02 Shortwall 03 Conventional Stoping 05 Continuous Miner 06 Hand 07 Caving 08 Other

6. Date of Accident

Month	Day	Year

7. Time of Accident ☐ am ☐ pm

8. Time Shift Started ☐ am ☐ pm

9. Describe Fully the Conditions Contributing to the Accident/Injury/Illness, and Quantify the Damage or Impairment

10. Equipment Involved | Type | Manufacturer | Model Number

11. Name of Witness to Accident/Injury/Illness

12. Number of Reportable Injuries or Illnesses Resulting from This Occurrence

13. Name of Injured/Ill Employee

14. Sex
☐ Male
☐ Female

15. Date of Birth

Month	Day	Year

16. Last Four Digits of Social Security Number

17. Regular Job Title

☐ 18. Check if this Injury/Illness resulted in death.

☐ 19. Check if Injury/Illness resulted in permanent disability (include amputation, loss of use, & permanent total disability).

20. What Directly Inflicted Injury or Illness?

21. Nature of Injury or Illness

22. Part of Body Injured or Affected

23. Occupational Illness (circle applicable code – see instructions)
21 Occupational Skin Diseases
22 Dust Diseases of the Lungs
23 Respiratory Conditions (toxic agents)
24 Poisoning (toxic materials)
25 Disorders (physical agents)
26 Disorders (repeated trauma)
29 Other

24. Employee's Work Activity When Injury or Illness Occurred

Experience	Years	Weeks
25. Experience in This Job Title		
26. Experience at This Mine		
27. Total Mining Experience		

● **Section D – Return to Duty Information**

Answer 30 & 31 when case is closed

☐ 28. Permanently Transferred or Terminated (if checked, complete items 29, 30 & 31)

29. Date Returned to Regular Job at Full Capacity (or item 28)

Month	Day	Year

30. Number of Days Away from Work (if none, enter 0)

31. Number of Days Restricted Work Activity (if none, enter 0)

Person Completing Form (name) | Title

Date This Report Prepared (month, day, year) | Area Code and Phone Number

MSHA Form 7000-1, Feb. 80 (revised)

For Official Use Only
Degree
Accident Type
Accident Class
Scheduled Charge
Keyword

10
Man
12
14
16
17
18
19
20
21
22
24

MAIL THIS PAGE TO THE HEALTH AND SAFETY ANALYSIS CENTER, MINE SAFETY AND HEALTH ADMINISTRATION, P. O. BOX 25367, DENVER, COLORADO 80225

Quarterly Mine Employment and Coal Production Report

U.S. Department of Labor
Mine Safety and Health Administration

Do Not Write In This Space

O.M.B. No. 44-R1761; Approval Expires December 1982

This report is required by law (30 U.S.C. § 813; 30 C.F.R. Part 50). Failure to report can result in the institution of a civil action for relief under 30 U.S.C. § 818 respecting an operator of a coal or other mine, and assessment of a civil penalty against an operator of a coal or other mine under 30 U.S.C. § 820 (a). An individual who, being subject to the Federal Mine Safety and Health Act of 1977 (30 U.S.C. § 801 et seq.) knowingly makes a false statement in any report can be punished by a fine of not more than $10,000 or by imprisonment for not more than 5 years, or both, under 30 U.S.C. § 820 (f). Any individual who knowingly and willfully makes any false, fictitious, or fraudulent statements, conceals a material fact, or makes a false, fictitious, or fraudulent entry, with respect to any matter within the jurisdiction of any agency of the United States can be punished by a fine of not more than $10,000, or imprisoned for not more than 5 years, or both, under 18 U.S.C. § 1001.

1. Fill out this form as completely as possible and return the first sheet of this report to
2. If it is necessary to make any address changes, indicate corrected information on this form.
3. When preaddressed, this form is only for the operation with I.D. number as shown; including contractor I.D. if appropriate. Do not use for any other operation.
4. SAND AND GRAVEL operators report employment data under code 03 or 06 as appropriate, except for data on office workers which should be reported under code 99.
5. All mine operators and independent contractors reporting as required by 30 CFR, Part 50, should show persons working and employee-hours worked; those producing coal show also production data.

MSHA, Health and Safety Analysis Center
P.O. Box 25367, Federal Center
Denver, Colorado 80225

DATE REPORT COMPLETED

MO | DAY | YR

FOR QUARTER

( )

MAIL BEFORE

1. Persons Working, Employee-Hours, and Coal Production

(1) Operation Sub Unit Code(s) previously reported:		Code	(2) Average number of persons working during quarter	(3) Total employee-hours worked during the quarter	(4) Production of clean coal during quarter, (short tons)
Underground Mine	Underground	01			
	Surface Shops, Yards, Etc.	02			
Surface Mine (including shops and yards)	Strip, Open Pit, or Quarry	03			
	Auger (Coal Mine Only)	04			
	Culm Bank or Refuse Pile (coal mine only)	05			
	Dredge	06			
	Other (Metal/Nonmetal Surface Mining)	12			
	Independent Shops or Yards	17			
Mill Operations, Preparation Plant, or Breaker (include associated shops and yards)		30			
Office (professional and clerical workers at the mine or plant)		99			

2. Other Reportable Data

How many MSHA reportable injuries or illnesses did you have this quarter?

	Name	Title	Phone (Incl. Area Code)
Person to be contacted regarding this report			

MSHA Form 7000-2 (Aug. 80)

▶ Check here if this report is being submitted by a contractor ☐

IF ANY INFORMATION BELOW IS INCORRECT PLEASE ENTER CORRECT INFORMATION HERE:

COUNTY ______

OPERATION NAME ______

OPERATING COMPANY NAME AND ADDRESS

______

______

______

MSHA I D NO CONTRACTOR I.D

COUNTY

OPERATION NAME

OPERATING COMPANY NAME AND ADDRESS

Return to MSHA

APPENDIX 4-B

CLASSIFICATIONS OF INJURIES AND ACCIDENTS

DEGREE OF SEVERITY OF INJURY

Degree	Definition
1	Death
2	Permanent total or permanent partial disability
3	Days away from work only
4	Days away from work and days of restricted activity
5	Days of restricted work activity only
6	Injuries that do not result in death or days away from work or days of restricted work activity

More detailed definitions are given below.

Degree 1

Fatality Injury resulting in death determined to be chargeable to the mining industry.

Degree 2

Permanent Total Disability Any injury or illness other than death that permanently or totally incapacitates an employee from following any gainful employment or that results in the loss, or complete loss of use, of any of the following: both eyes; one eye and one hand or arm or leg or foot; any two of the following not on the same limb--hand, arm, foot, or leg.

Permanent Partial Disability Any injury or illness other than death or permanent total disability that results in the loss, or complete loss of use, of any member or part of a member of the body, or any impairment of functions of the body or part thereof, regardless of any preexisting disability of the affected member or impaired body function. The following are not classified as permanent partial disabilities:

a. Inguinal hernia, if repaired. An unrepaired inguinal hernia is classified as a permanent partial disability with a time charge of 50 days away from work, but when repaired and so reported to MSHA it is reclassified as degree 3 and the time charge is replaced by actual days away from work.

b. Loss of tip of a finger or tip of a toe without involvement of the bone. The loss or removal of the tuft of the bone in the distal phalange of a finger or toe is considered involvement of the bone provided it shows in X-rays.

c. Loss of permanent teeth.

Degree 3

Nonfatal injuries that do not result in permanent impairment but that render the injured person unable to perform a regularly established job that is open and available to him during the entire time interval of his regular shift. The number of days away from work does not include the day of injury or onset of illness or any days on which the miner would not have worked even though able to work.

If any employee loses a day from work solely because of the unavailability of professional medical personnel for initial observation or treatment and not as a direct consequence of the injury or illness, the day is not counted as a day away from work.

Degree 4

Days Away from Work and Days of Restricted Activity Nonfatal injuries that begin as degree 5 and later cause lost work days, or injuries that began as degree 3 and later cause restricted work activity.

Degree 5

Days of Restricted Work Activity Only Nonfatal injuries that do not result in permanent impairment or days away from work. These include the number of days that a miner is assigned to another job on a temporary basis, a miner works at a permanent job less than full time, or a miner works at a permanently assigned job but cannot perform all of the duties normally connected with it.

The number of restricted days does not include the day of injury or onset of occupational illness or any days the miner does not work even though able to work. If an injured or ill employee has scheduled follow-up medical treatment or observation that results in the loss of a full workday solely because of the unavailability of professional medical personnel, it is not counted as a day of restricted work activity. Days of restricted work activity end as a result of any one of the following: the miner returns to his regularly scheduled job and performs all of its duties for a full day or shift, the miner is permanently transferred to another job, or the miner is terminated or leaves the mine.

Degree 6

No Lost Time Injuries Injuries that do not result in death, permanent impairment, days away from work, or restricted work activity.

CLASSIFICATIONS OF ACCIDENTS

Following are the definitions used to classify accidents. The accident classification identifies the circumstances that contribute most directly to the resulting accident. The accident may or may not be directly tied to any consequent injury. The classifications are listed in alphabetical order.

1. Electrical Accidents in which electrical current is most directly responsible.
2. Entrapment In accidents involving no injuries or no serious nonfatal injuries, entrapment of mine workers (as an accident class) takes precedence over roof falls, explosive accidents, inundations, etc.
3. Exploding Vessels Under Pressure Accidents caused

by air hoses, air tanks, hydraulic lines, hydraulic hoses, or other exploding vessels.

4. Explosives and Breaking Agents Includes accidents caused by Airdox and Cardox.

5. Falling, Rolling, or Sliding Rock or Material of any Kind Injuries caused directly by falling material. If material is set in motion by machinery haulage or hand tools, the force that sets the material in motion is charged. For example, if a rock is pushed over a high-wall by a dozer and hits another rock, which hits and injures a worker, the dozer most directly caused the resulting accident.

6. Fall of Face, Rib, Side, or Highwall Since pressure bumps and bursts that cause accidents are infrequent, they are not given a separate category.

7. Fall of Roof or Back Underground mines only. Includes accidents while barring down but not surface structure failure.

8. Fire An unplanned mine fire not extinguished within 30 minutes of discovery. Fires of shorter duration may be responsible for reportable injuries. In those cases, the fire is still the causative accident.

9. Handling Material Accidents caused by lifting, pulling, pushing, or shoveling material. The material may be in bags, boxes, or loose. The accident has to be most directly caused by handling material.

10. Hand Tools Does not include electric tools or air-powered tools.

11. Nonpowered Haulage Includes wheelbarrows, manually pushed mine cars and trucks, etc. Motion of haulage must cause the accident.

12. Powered Haulage Haulage includes motor and rail cars, conveyors, 980 cat loaders, shuttle cars, haulage trucks, front-end loaders, load haul dumps, CAVO, fork-lifts, etc. Motion of the haulage must cause the accident. If a car dropper suffers an accident by falling from a moving car, haulage is charged with the accident.

13. Hoisting Damage to hoisting equipment in a shaft or slope that endangers an individual or interferes with use of the equipment for more than 30 minutes. Hoisting equipment may also be the classification if a victim is injured by hoisting equipment but there is no damage to the equipment. It includes accidents involving cages, skips, ore buckets, elevators, etc. The accident has to result from the motion of the hoisted platform--for instance, a skip squeezed between timbers, or an ore bucket tipped for any reason.

14. Ignition or Explosion of Gas or Dust An unplanned ignition or explosion of gas or dust.

15. Impoundment An unstable condition at an impoundment, refuse pile, or culm bank that requires emergency action to prevent failure or that causes individuals to evacuate an area. Also, failure of an impoundment, refuse pile, or culm bank.

16. Inundation An unplanned inundation of a mine by a liquid or gas. The mine may be either a surface or an underground mine.

17. Machinery Includes electric and air-powered tools, mining machines, loaders, slushers, draglines, power shovels, etc. The motion of the machinery has to cause the accident.

18. Slip or Fall of Person Includes stepping in a hole, falling while getting on or off machines or haulage equipment that are not moving, and falling from machines or haulage equipment while servicing or doing repair work.

19. Stepping or Kneeling on Object Accidents can be charged to this category only when the object stepped or kneeled on contributes most directly to the accident.

20. Striking or Bumping Does not include accidents that occur while handling material, using hand tools, etc.

21. Other Last resort category.

APPENDIX 4-C

AGE DISTRIBUTION SURVEY FORM

Controlling Company:______________________________

Please complete and return to:

Prof. Stephen Lagakos
Department of Biostatistics
Harvard University School of Public Health
677 Huntington Avenue
Boston, MA 02115

Instructions: For each year, enter the percentages of underground miners in your company that fall into each of the age categories. If you have any questions, or if you record age information in a way not conducive to these categories, telephone Stephen Lagakos at 617-732-3601.

PERCENTAGE OF UNDERGROUND MINERS

Year	18-24 years old	25-34 years old	35-44 years old	45 years and older
1978				
1979				
1980				

____
Your name

APPENDIX 4-D

MULTIVARIATE REGRESSION METHODOLOGY

With the exception of the linear Poisson regression of R_{12} onto R_{INT} in Figure 16, all regression analyses are based on a log-linear Poisson model. Suppose n denotes the number of injuries of a particular kind that occur in a mine over a given period of time in which there are T employee-hours. The model assumes that n has the Poisson distribution with rate parameter λT, where λ is the expected number of injuries per unit time. We parameterize λ as a log-linear function of mine characteristics. Specifically, if $Z = (Z_1, Z_2, \ldots, Z_p)$ are mine characteristics such as size, seam thickness, state, etc., then

$$\lambda = \exp(\alpha + \beta Z),$$

where α and $\beta = (\beta_1, \beta_2, \ldots, \beta_p)$ are regression coefficients to be estimated. Thus the hypothesis that mine characteristic Z_j is not associated with injury rates is given by $\beta_j = 0$, and the injury rate ratio corresponding to two levels, say Z^* and Z^{**} of Z_j, is $\exp\{\beta_j(Z^* - Z^{**})\}$.

Analyses of models are based on the method of maximum likelihood, with computations carried out by GLIM, an interactive package for fitting and testing statistical models.* Rewritten in GLIM notation, the model has the form

$$n = \exp\{\ln T + \alpha + \beta Z\} + \epsilon,$$

where ϵ denotes the Poisson error structure.

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*Baker, R. J., and Nelder, J. A. (1978) Generalized Linear Interactive Modeling, Royal Statistical Society, London.

The specific mine characteristics considered in our analyses were

Z_1 = seam thickness = 1 if 0 to 48 in.
2 if 49 to 60 in.
3 if 61 to 72 in.
4 if 73 to 84 in.
5 if over 84 in.

Z_2 = mine size = 1 if 1 to 50 employees
2 if 51 to 150 employees
3 if 151 to 250 employees
4 if over 250 employees

Z_3 = union status = 0 if nonunion
1 if union

Z_4 = productivity = 1 if 0 to 0.75 tons/employee-hour
2 if 0.75 to 1.0 tons/employee-hour
3 if 1.0 to 1.25 tons/employee-hour
4 if 1.25 to 1.5 tons/employee-hour
5 if over 1.5 tons/employee-hour

and the categorical variables state (or location) and company. The latter two are incorporated into the model using binary indicator variables: Z_5 through Z_{11} for Alabama, Illinois, Kentucky, Ohio, Pennsylvania, Virginia, and West Virginia, and Z_{12} through Z_{30} for the 19 companies. Thus $Z_5 = 1$ and Z_6 through $Z_{11} = 0$ represents the state of Alabama, and Z_5 through $Z_{11} = 0$ represents a state other than the seven named above. The injury count n is taken to be either the number of disabling injuries or the number of fatalities, and the time periods used are 1978-80, 1975-77, and 1975-80. Numerous regressions were carried out based on different combinations of mine characteristics, different subsets of the data (e.g., separate regressions for each state), and different injury counts and time periods.

To illustrate, fitting Z_1 through Z_{11} for disabling injuries in 1978-80 yields the following estimated regression coefficients and corresponding standard errors:

$\hat{\alpha} = 3.91 \pm .041$
$\hat{\beta}_1 = -0.071 \pm .0051$
$\hat{\beta}_2 = 0.023 \pm .0067$
$\hat{\beta}_3 = 0.44 \pm .031$
$\hat{\beta}_4 = -0.006 \pm .0045$
$\hat{\beta}_5 = -0.18 \pm .037$
$\hat{\beta}_6 = 0.21 \pm .032$
$\hat{\beta}_7 = -0.52 \pm .034$
$\hat{\beta}_8 = 0.16 \pm .033$

$$\hat{\beta}_9 = 0.12 \pm .029$$
$$\hat{\beta}_{10} = 0.067 \pm .032$$
$$\hat{\beta}_{11} = -0.086 \pm .028$$

Thus while $\hat{\beta}_2$ is significantly different (statistically) from zero, the magnitude of the effect is so small that it is of little or no consequence and could easily be explained by mine characteristics not included in the regression. By contrast, the magnitude of the coefficients for union status and several of the states is much larger.

5

MINE VISIT REPORTS

INTRODUCTION

In order to answer the question "Why are some underground coal mines safer than others?" the Committee felt it was important to visit a number of underground coal mines, some with low injury incidence rates, others with high injury rates. The Chairman appointed three teams, each consisting of three members; each team was headed by a mining engineer. The team captains selected the mines to be visited; each team visited four mines. We decided to concentrate on the larger underground mines, those having an average employment of 150 workers or more, because collectively these mines employ two thirds of the underground coal mine workforce, and hence they are more representative of the industry as it exists today.

The Committee developed a set of 28 questions to serve as a guide, but the teams were encouraged to follow their own course in conducting interviews with miners and management personnel. As a result the mine visit reports differ in the emphasis they give to the various factors relevant to safety. No attempt was made to cast these reports into a uniform format, but the reader will note much similarity in approach, since each team attempted to explore principal subjects that are relevant to mine safety.

Table 27 summarizes the disabling injury rates and several mine characteristics of the 12 mines visited by the Committee. The first two of these characteristics, which we believe to be causally related to injury rate, are the quality of labor relations and several qualities that are illustrative of management's commitment to safety--a proper balance between production and safety,

TABLE 27 Comparison of Injury Rates and Certain Qualities of Underground Coal Mines Visited by the Committee

Mine	A	B	C	D1	D2	E	F	G	H	I	J	K
Injury rate for 1980	5.6	1.8	3.9	4.2	7.8	1.8	0	35	21.7	63.9	16.7	43
Management commitment												
A. Production and safety balanced	yes	yes				yes	yes		no			
B. Good safety meetings and regular contacts	yes	yes	yes	yes			yes	no			yes	
C. Safety rewarded				yes		yes			yes			
D. House-keeping		good		good						poor		
Labor relations	good	good	good	good	improving	good	good	poor	poor	poor		
Absentee rate (percentage)	15-17	10	low	low	average	7	10	25	15-16	22-23		16

safety meetings and contacts, rewards for safety, and good housekeeping in the mine. The other characteristic is absenteeism rate, whose association with injury rate could not be determined in our statistical analyses because industry-wide data were unavailable.

We see from the table that our observations in the 12 mines support our belief in the importance of management's commitment and labor relations. In particular, all mines with low injury rates gave evidence of a cooperative attitude between management and labor; an adversarial attitude was observed in three of the mines with high injury rates. It is also apparent that the mines with higher injury rates tended to have higher absenteeism rates. Of course, with so small a sample, no generalization can be made about the association between absenteeism and injury rate in all mines.

In our letter requesting permission to visit each mine, we stated that we would not, in our report, identify the mine or the company by name, but that the information we obtained would be used by the Committee and would influence our findings and conclusions. The mine visit reports were distributed to all members of the Committee and constituted an important information resource in preparing this final report. We felt it important to provide the reader with this resource information, and we do so by presenting the mine visit reports in this chapter.

Table 28 gives the schedule of mine visits, the date each mine was visited, and the visiting team. Actually, there are only 11 separate reports, since two mines of one company were visited as a pair and are covered in one report.

The reader will note that some mine managers (though not all of them) expressed severe criticisms of inspectors from the Mine Safety and Health Administration (MSHA). That this attitude on the part of mine managers exists and is widespread must be reported. However, the Committee found no evidence that supports or that justifies this adversarial attitude. By contrast, miners and union committeemen interviewed in these mine visits spoke well of federal inspectors' attitudes and abilities.

In Chapter 2, the Committee recommends continued enforcement of existing state and federal mine safety laws. Enhancement of MSHA's advisory functions is also recommended, but as a separate activity, distinct from enforcement.

TABLE 28 Schedule of Mine Visits

Team	Mine	Date Visited
Zegeer Damberger Lewis	Mine A	July 28, 1981
Spokes Mullins	Mine B*	July 21, 1981
Wright DeReamer Rosen	Mine C	July 23, 1981
Spokes Mullins	Mines D1 and D2*	July 23, 1981
Zegeer Damberger Lewis	Mine E	July 29, 1981
Zegeer Damberger Lewis	Mine F	July 27, 1981
Spokes	Mine G*	August 18, 1981
Wright DeReamer Rosen	Mine H	September 3, 1981
Wright DeReamer Rosen	Mine I	July 16, 1981
Zegeer Lewis	Mine J*	August 18, 1981
Wright DeReamer Rosen	Mine K	September 2, 1981

*Other members of the team were not available for these mine visits.

VISIT TO MINE A BY ZEGEER, DAMBERGER, AND LEWIS, JULY 28, 1981

During 1980 the four mines in this district produced approximately 2,560,000 tons, a decrease of about 130,000 tons from the previous year. The district employs about 750 underground miners, with a total of about 1,000 wage earners and 200 salaried workers. The cleaning plant employs 104 workers. The district also has a central shop.

Our contacts during the visit were the general superintendent, the assistant general superintendent, and the mine superintendent. The general superintendent, our primary contact, is young, has worked in the mines for 10 years, and is fifth generation in coal mining.

Technical Information

The mines produce a highly volatile bituminous coal of low sulfur content that is used in making coke. Average figures for the coal are 36 percent volatile matter, 6.5 percent ash, and 0.9 percent sulfur. All of the coal is washed together in one central cleaning plant, which processes about 18,500 tons of raw coal per day at about a 65 percent yield.

The mines above drainage have essentially no methane. The mine below drainage has a little methane. The roof is sandstone and shale, with rider coals 1/2 to 100 ft above the mined coal. If rider coal is within 1 ft of the coal, the shale is taken down.

All mines are room and pillar. The company plans to do longwall mining for the first time next year in 10-ft-thick coal; it will be done on retreat. Roof control is by standard mechanical bolts. Pillars are not recovered in thick coal, but they are in thinner coal. Management keeps track on a map of unintentional roof falls. They do not consider roof failures a major problem. The last fatality was in April 1980 under unsupported roof; a miner helper was the victim. There have been four fatalities since 1966.

Labor Relations

The average age of the employees is 32. In 1971, it was 47. In 1975-76, it was 29. The miners are organized in the United Mine Workers (UMW). They have only one local for all four mines, which both the company and the union consider advantageous. The general superintendent sees labor-management relations as excellent with very few grievances. Hiring often runs in families, but the company has standard procedures to avoid discrimination against minorities. The district has 22 to 25 percent black workers and 40 to 45 women on the workforce. The workforce is quite steady, consisting of families who have worked for the company for years. Until 1963 the company owned the houses the workers lived in. Stealing is a cause for dismissal; recently a miner was dismissed for stealing after he had been warned by his foreman. A foreman was also fired in 1980 for his work record.

An average of 15 to 17 percent of the workforce is absent at any given time, with about 7 to 8 percent of that unexcused. A few miners have been dismissed for excessive absenteeism. The general superintendent believes that absenteeism is one of the leading reasons for accidents. He believes that training workers to be substitutable makes for safer operations but says that the company is hampered by regulations, its own policies, and the union contract.

Safety Training

All safety training is done according to job safety analysis booklets. About 20 percent of the safety training (the initial training of new employees and the required maintenance training) is done at the central shop; 80 percent is done directly at the mine. Most training is on a one-to-one basis. The state requires that no new employees be permitted to run equipment for the first 90 days of their employment. New employees tend to be used as "flunkies" during this period; they are eager to get it over with. The district has no training mines or training sections.

The company has a five-person safety department for the four mines and surface facilities, with one chief mine inspector, one senior inspector, two junior inspectors, and one maintenance-training person. These personnel inspect mines but are also in charge of initial and maintenance safety training. Their inspections are tougher than those of MSHA, according to the general superintendent.

All miners receive eight half-day sessions and one eight-hour session per year of safety training. In the eight-hour session two hours are on the surface; during the other six hours the miners are trained in their respective sections, with specific safety instructions. This is normally done section by section, by the foreman, on Saturdays at the company's expense.

All foremen are trained in first aid; 60 to 70 percent of the foremen have electrician's certificates. Through a year they are exposed to various safety-related programs. New foremen get a three-week training program in safety; others get two-week refresher courses each year. Superintendents and other management also are exposed to about five to seven weeks of safety training. The foremen do work-hazard analysis and use strike time for training in accident prevention and safety.

Each mine elects a safety committeeman. The company pays these committeemen for walk-around inspections. Once a month the committeemen meet with the general superintendent and the chief inspector. The general superintendent described the situation as "steady" over about the past 10 years.

Section foremen handle safety complaints where and when they occur. If not satisfactorily resolved, the problem goes to the safety committee, to the general foreman, to the general superintendent, and finally to MSHA or the state. In the past few years only two safety grievances have gone to the district. The general superintendent thinks that the system works well and "keeps both sides honest."

Because the coal division has recently gone commercial it has to be cost competitive. The general superintendent is concerned about total resource use and believes that resource development should be planned to care for reserves and not to mine high-grade coal selectively. "Smaller operators often destroy reserves by gobbling up the best," he said. He worries that if the division becomes too commercial or competitive, it will not be as safety conscious or plan resource development as well.

Visit to the Mine

The mine we visited is exceptional in two ways: It has the highest productivity of all the company's mines, and the men working in the mine are used to visitors; they have been studied by the General Accounting Office for productivity and by MSHA for mine safety. The mine had an injury rate of 5.6 (degrees 1-5) in 1980.

We were introduced to many workers and given an opportunity to talk with them. It was a relaxed and friendly atmosphere, and the miners were open, talkative, and cooperative. In the past 10 years the mine has lost 11 days on strike (not counting contract strikes), and 7 of the 11 days were due to outside pickets. Discipline problems are handled through the union.

The miners said that the company does not rush them, that it does not push production. One miner told of working with another company and said it was all the difference in the world; the other company pushed you. Another said that he ran his own small mine before coming to this company and that it was much safer here, partly because of new techniques and the laws. He said that the laws were needed. One miner suggested that other mine operators should be sent to this company to learn how to run a mine safely. The men spoke well of the safety meetings and said they were taken seriously, were well planned, and were not just gossip.

We talked to one of the young company inspectors, who is a student at the community college mining program. He was making a written report of things that needed fixing. He said that the company took his reports seriously and would fix the things he recommended.

The coal is mined under 400 to 600 ft of cover. The mine is spread out near the top of the mountain, with generally easy access from the outside. They have several portals along the crop line of the seam. Most section crews can therefore enter the mine close to their active section. The maximum walk takes about 20 minutes.

There are no rails in the mine; they use battery-driven cars for transportation. They have 6 miles of conveyor belts (42 and 36 in. wide) in the mine to bring mined coal to a central dumping point, where a wide hole has been drilled to drop coal to the level of the railroad track for loading.

Belt lines are checked at least once every eight-hour shift; a written report is made of the findings. Inspectors use a tape recorder while riding the belt to make the inspection. Each section has a battery-driven car available so that a hurt miner can be brought outside quickly and met by the ambulance.

We were taken to the D43 portal. The seam is 48 to 54 in. thick. They use 3-ft and 4-ft mechanical bolts. All roof-bolting machines in this mine have Fletcher temporary support beam fronts plus a 15-ton hydraulic jack on both sides. Each roof bolter has a steel plate canopy that can be swung so that the bolter stands under it while drilling the hole for the roof bolt. Continuous miners do not have canopies because they want to have at least 9 in. of clearance, but here they would only have 3 to 4 in.

VISIT TO MINE B BY SPOKES AND MULLINS, JULY 21, 1981

We met briefly with the executive vice president of the company, the vice president of operations, and the manager of corporate safety. Most of our information came from the underground mine inspector (for the corporation), the ventilation and safety engineer, the retiring inspector of Mine B, his successor, and the safety inspector. We met very briefly with the mine superintendent.

Mine B has 477 employees and an annual production of about 1,300,000 tons. It operates two longwall faces and five or six continuous miner sections, depending on the availability of crews and machines. Usually a section operates two shifts and the third is used for maintenance, with the maintenance shifts staggered so that there is continuous production. Crews customarily work in one area, using replacement machines when equipment breaks down. The absentee rate is about 10 percent, which is one of the best rates in the company's mines. Replacements are made within each section's working crew. The mine had an injury rate of 1.8 (degrees 1-5) in 1980.

Safety Program

Foremen submit written reports on all accidents, whether or not there is personal injury; a lost time accident report must go to MSHA. Standard MSHA forms are used. Mine inspectors assist in investigating accidents. The physician treating any victim also submits a medical report.

Accident reports are logged by the inspector at each mine and are forwarded to the corporate underground mine inspector and the manager of corporate safety. Here the statistics are assembled by mine and a summary is prepared each month showing the production and safety to date that year (the production reported is tons of raw coal as fed to the preparation plant). These are then presented at a monthly meeting of the general superintendent, the mine superintendents, and all safety department employees; the information can be used by the attendees as appropriate to improve safety.

Each working area of the mine is inspected at least once in three days by one of the four safety inspectors; the mine is inspected also by an electrical inspector and by one of two dust samplers at regular intervals. Deficiencies are noted and must be corrected, usually on the next shift, and the section foreman must initial the report before it goes to the corporate safety office. The safety department can close down a section of the mine in case of imminent danger.

Housekeeping and underground working conditions appear to be satisfactory. Observance of safety rules appears to be good, although the safety department reported some resistance to the wearing of safety glasses. Management's commitment to safety appears to be high.

Role of Management, Labor, and Government

Management employees are held responsible for safety. Although no manager has been fired up to this time, the possibility exists; at least one boss has been suspended for failure to abate a hazard. Records of accidents and MSHA violations are available for evaluating each boss.

All supervisors receive the legally required training and annual retraining; there are special courses in mine safety for section bosses. The manager of corporate safety is a graduate engineer, but there is no external educational requirement beyond high school for the subordinate positions; training for these jobs is internal. Only the safety manager attends meetings of national safety organizations.

Union safety committees are elected by the members for two-year terms; capability and interest in safety are deciding factors in voting. Members can be reelected. The committee works closely with management and receives strong support. Committee members take little part in section safety meetings unless there has been an accident on the section.

MSHA inspections are recognized as a legal requirement, but the safety department inspectors feel that they are in control of the safety situation and that the quarterly MSHA inspections keep them from doing more important work.

Roof Control

The roof control plan was prepared by a graduate engineer who was then the corporate underground mine inspector. The plan was based on tests made in a section, using torque, pull, and plate tests to determine proper spacings and bolt lengths. Roof geology was considered. Bolts are 5 ft in length, either 5/8-in. high-strength steel with conventional anchor or 3/4-in. reinforcing bar with resin anchor. In entries and rooms of 14-ft to almost 21-ft widths, bolts are on 5-ft centers.

The bolters have the authority to use closer spacings, and this precaution appears to be normal rather than exceptional; bolters said that they never were accused by management of using too many bolts, which are a costly item. There is some use of resin-anchored trusses. In some areas supplemental bolts 9 to 12 ft long are used with conventional anchors because of slips. Posts and cribs are also used. The roof is not easy to maintain; since April 1978 there have been 49 falls above bolts.

All roof falls above bolts are reported to MSHA. No records are kept of falls of face coal, falls of roof coal before bolting, or falls between bolts. One major roof fall site was visited. Two intersecting slip faces formed a natural dome. It had been bolted to the top of the opening, with very close spacings between bolts and frequent overlapping of plates.

Training

All miners receive the MSHA required training and are trained for individual jobs, such as miner operator, by being instructed first on a machine not in production, then on that machine while operating, then in a production situation while operating under observation by a training department instructor. There is the usual annual refresher course on safety. Section foremen have a special training course. There is relatively little attendance by safety personnel at meetings and training courses outside the company.

Postaccident Activities

Each mine section has a fully equipped first aid station, and emergency medical technicians (EMTS) are close by.

When an accident occurs, the fire department ambulance is called and is waiting when the victim reaches the surface. The ride to the hospital takes seven minutes.

It is required that all safety workers be emergency medical technicians; in addition, three mine managers and three assistant mine managers, as well as some section foremen, are EMTs. All miners take first aid and cardiopulmonary resuscitation (CPR) training.

Accident reports of all types are logged in the mine safety office and go to the district safety officer. There they are assembled and summarized in the monthly report. Accident victims remain on compensation until they are ready to resume their regular jobs. This requires clearance by the company physician.

Summary

An outstanding strength of the company's safety program, as seen by the safety staff, is the open-door policy that permits any worker to come in and discuss a hazard. Other strengths are the prompt abatement of hazards and the company's support of safety versus production.

The safety program had no apparent weakness, but the team's impression was that more effort should be devoted to contact with the National Safety Council and similar organizations to keep the program up-to-date.

Labor and management appear to work well on safety issues. There was a wildcat strike on an issue not related to safety when we were at the mine.

VISIT TO MINE C BY WRIGHT, DEREAMER, AND ROSEN, JULY 23, 1981

Mine C, which has been operating for 20 to 30 years, produced 921,000 tons of coal in 1980. Its average employment is 319; the mine had an injury incidence rate (degrees 1-5) of 3.9 in 1980.

Production is from one longwall section and seven continuous miner sections. The longwall panels are 450 ft wide and 3,000 to 5,000 ft long. The seam varies in height from 6 to 14 ft, averaging 7 to 9 ft. There is a 7 percent grade from the entry down to four longwall sections that are planned for mining in the near future.

A bad top and water are the principal problems in this mine. There is no methane; if there were, this in combination with the water and the bad roof might discourage working the mine. The output is sold mainly to an electric power company. The area currently being worked in the mine is particularly bad (having much interbedded rock) and is running 53 percent reject. The raw coal has 3 to 3.5 percent sulfur, a figure that is reduced to 1.85 percent after cleaning.

The people we spoke with included the division safety director, who acted as our guide for the visit, the district general manager, the mine superintendent, the general mine foreman, the safety inspector, the safety committee chairman, a section supervisor, a section foreman, a continuous miner operator, a shift mechanic, and several other miners.

The mine has a drift entrance; we traveled by rail for 2.5 miles to the working area. We visited two sections; in the first a continuous miner and roof bolter were preparing a longwall for operation. However, both the continuous miner and the roof bolter were out of operation because of an electrical supply problem (thought to be a short in the power supply line). The continuous miner entries appear to be cleanly cut with an even roof about 8 ft high; the roof is coal. In the second section we saw a longwall machine that was down for repair. The 450-ft face is cut by a ranging drum shearer. The roof is supported by 94 shield-type supports.

Safety Program

The division safety director, who has an M.S. degree in safety management, is responsible for safety reports to MSHA for the division. He feels that the company's injury report records are very close to MSHA's and that the reporting policy is fairly uniform throughout the company. He believes that the high workman's compensation rate in the state encourages men to stay off who should be working, but the division takes steps to combat this tendency. They employ a full-time compensation director who investigates each case, works with local doctors, and encourages the doctors to be sensible about compensation awards. This procedure seems to have worked well. The company uses job safety analysis. They have a procedure for each job category, and responsibility for task training rests with the foremen. A safety observation program for foremen on a twice monthly basis has just been started.

Safety personnel monitor the activities of miners and management. They inspect each area of the mine at least weekly, correct individuals on the spot, and record unsafe practices. All accidents and injuries are investigated by the immediate supervisors and by the safety inspectors; records are kept on all injuries no matter how minor. Unintentional roof falls and other accidents with or without injuries are recorded and investigated. The company has an elaborate training department that is separate from the safety department.

The division safety director feels that the industry is overregulated. He feels that inspectors should emphasize accident prevention rather than citations. The mine averages 30 to 35 violations per quarterly inspection. According to the director, state inspectors are more practical and realistic about mine problems.

There is no doctor or medical service at the mine. For serious injuries a hospital about 20 miles distant is called, which will send an ambulance. The division has a training facility for first aid on the site; 50 percent of supervisory employees have had emergency medical training.

Mine Management

Management personnel in general feel that MSHA inspectors should be involved in accident prevention rather than enforcement, that there are too many regulations, and that the company is so engrossed in compliance that it does not have time to concentrate on prevention.

Toward the end of our visit we met the district general manager. We asked him why in his opinion some mines were safer than others, and he gave the following reasons: the good mines have a good safety program and experienced people (referring principally to the miners).

Housekeeping in this mine seemed better than in others we visited. The track was in good condition and the equipment seemed well maintained, even though we were held up for about an hour (on our way out) by track repairs. All told we were underground 4-1/2 hours, giving us time to talk with a number of miners and foremen. One section supervisor feels that there is a good relationship between labor and management, especially in recent years. In 1969 there were strikes every week, but the situation has improved every year since that time.

Safety Committee

We met the chairman of the safety committee, who is also a vice president of the local union. He has attended the union safety seminar at Beckley, West Virginia. He believes government inspectors are doing a good job, especially when he points out problems to them. He speaks well of the mine superintendent and believes there is a good attitude between labor and management at this mine.

Roof Control

The mine has poor roof conditions, but it is kept under control by 5-ft resin bolts installed by Fletcher roof bolters with automated temporary roof support systems. Rib rolls also give problems at this mine.

Summary

This mine has a good safety record. There appears to be a good relationship between management and labor. The company has pursued an aggressive policy to reduce the number of lost time accidents due to dubious injuries and also to reduce absenteeism.

VISIT TO MINES D1 AND D2 BY MULLINS AND SPOKES, JULY 23, 1981

We visited two mines owned by the same company and located within a few miles of each other; hence the geological conditions should be similar. Mine D1 had an injury rate of 4.2 in 1980; for D2 the rate was 7.8, almost twice as high. One purpose of our visit was to see if we could explain the difference in injury rates between the two mines. At Mine D1 the management personnel we interviewed included the mine superintendent, a surveyor, a safety inspector, the assistant mine superintendent, a section foreman, and an engineer. At Mine D2 we talked with the safety supervisor, the mine superintendent, the chief safety inspector for the region, and others.

General Impression at Mine D1

There is a definite esprit at this mine; it is apparent that morale is high. The miners appear to take pride in their work, in the quality of labor-management relations, in their safety record, and in the generally cooperative spirit that seems to prevail at the site. There seems to be a perception among the miners who were interviewed that management officials are readily accessible and genuinely interested in, and responsive to, their problems. Miners who had worked at other mines commented on the definite contrast between working conditions at this site and at mines where they had previously been employed.

Management at all levels seems to be aware of this high morale and actively fosters a spirit of cooperation. For example, a section foreman who was interviewed stated that in the past year he could recall only three or four occasions when he needed to give a direct order to any individual regarding work to be performed. He said that all he needed to do was to point out or suggest that some action was needed and the men did it. He commented favorably on the constant initiative and cooperation displayed by the men. Work activities are almost always performed without quibbling about whose job it is, he said.

This apparent spirit of trust and cooperation does not seem to have been achieved through the abdication of their roles by either management or labor representatives. Management officials seem to recognize that the workforce at this mine has a cooperative spirit, enthusiasm, and interest in what is happening at the mine and within the company. Management seems determined to reinforce this atmosphere by maintaining clear and open lines of communication and by fostering the perception among the miners that this mine is an excellent place to work. Miners expressed considerable satisfaction with management personnel and policies. There seems to be a feeling among the miners that management responds promptly to complaints and takes steps to respond to those complaints without quibbling, footdragging, or hostility.

Factors Contributing to Conditions at Mine D1

A number of factors appear to contribute to conditions at this mine: (1) the attitude and conduct of mine management; (2) the attitude and conduct of the miners and their representatives; (3) the perception of mine management and its policies held by the miners and their representatives; (4) the stability of the workforce; (5) the experience of the workforce; (6) the size of the workforce; and (7) a bonus program that incorporates both safety and production as factors in a financial incentive and that makes an informal status report of the estimated bonus constantly visible to the miners.

Attitude and Conduct of Mine Management

Mine management fosters open communication, accessibility, and feedback. All foremen attend a mine management school that stresses human relations. With more particular reference to safety matters, mine management, at the headquarters level down to the section foremen, displays a commitment to safety in various ways. Inspections by higher-level company safety officials occur at least quarterly and are, according to local mine management, "tougher than the feds." Regional-level officials are perceived by local mine management as knowledgeable and informed about the mine's safety record.

In general, mine management seems to regard the various safety and training requirements required by law as only a starting point, and there appears to be no hesitation to require more than the legal minima. For instance, new miners, by company policy, are required to wear a red hat during the 45-day period of additional, closely supervised, on-the-job training required by the union contract. Local mine management estimates that for each MSHA Form 7000 injury report, the company requires five or six additional internal company reports. A company report is required for any incident involving any injury, no matter how slight. In addition, at the local level at least, close attention is paid to "near misses" that could have resulted in injury. Any incident that had the potential for serious injury would result in additional internal company reports and recommendations for curative or preventive actions.

Safety personnel have the authority to halt production and require the correction of unsafe conditions, and they appear to feel confident of higher-level company support for such actions if any conflict arises at the mine level. Every section foreman is accountable for safety. A foreman's training in safety matters approaches that required of safety personnel.

Local mine management perceives upper levels of management as serious about safety and tough-minded about carrying out safety policies. Local mine management seems to have no doubt that a supervisor's carelessness, unsafe acts, or condonation of unsafe acts by miners would result in discipline or discharge of the supervisor.

Section foremen are responsible for training individuals on new tasks. In addition, foremen carry out a program called Safe Work Instruction. The foreman observes a certain minimum number of workers each week carrying out their regular work assignments, discusses his observations with the individual, corrects any deficiencies noted, and turns in a report to the safety director. The safety director meets weekly with mine foremen, and mine foremen hold safety meetings each week for 15 to 30 minutes with their crews.

Mine management regards the union safety committee as a positive benefit that adds "six more eyes" to check for safety matters, in the words of one local manager.

Stability and Experience of the Workforce

The workforce, approximately 110 hourly employees on two production shifts and one maintenance shift, is remarkably stable. The last new hiring was three years ago. Absenteeism is well below that reported for other mines, but precise figures were not obtained. The average age and experience level are probably higher than at many other mines. Mine management and miners indicated that most miners are experienced and cross-trained on various tasks, so that absences from work cause little or no disruption.

Bonus Program

The company at this mine is able to maintain a bonus system that incorporates both production and safety factors in calculating the amount of a bonus. Roughly 40 percent of any bonus is attributable to a good safety record. While such a system might mask a few reportable injuries and create some peer pressure to return to work after injury sooner than advisable, it also removes some of the incentive that might otherwise exist to exaggerate minor injuries and malinger for a few days. Control over returning to work prematurely is achieved by requiring clearance from an individual's doctor.

Specific Information on Mine D1

Housekeeping and general working conditions in Mine D1 and on the surface are generally good. Materials on the surface are usually stacked in orderly fashion. Unnecessary debris and accumulations of waste and other materials seem minimal. Existing safety rules seem to be observed, with the possible exception of some laxity on safety glasses.

The roof, even when bolted, is in poor condition. Roof bolts are all at least 10 ft long with double anchors. Much light sloughage was observed on travelways. Pull tests and drill holes are used to test the roof, and drilling is at least 1 ft above the normal length on the first hole at the start of each shift.

The original bolting plan was worked out in the mid-1960s based on test runs in an unused entry (an airway). At that time 8-ft bolts were adopted, but roof failures caused management, about 1969, to change to 10-ft bolts with two expansion anchors per bolt.

Extra supports are used; timbering, etc., was observed along various travelways. A temporary roof support system is used by roof bolters at the face for additional protection. All roof falls that involve breaking above anchorage are documented and reported to MSHA, as required.

There are indications of occasional oral reprimands by section foremen because of unsafe conduct by employees. No record is kept of such matters. The company has not found it necessary to impose formal discipline for unsafe acts. The consensus of miners interviewed seems to be that a serious unsafe act could result in discharge and that if the individual were clearly in the wrong, and had endangered other miners by such conduct, the matter would probably not be taken to arbitration by the union.

All injuries are reported to higher management. Many near misses are also reported, although there do not seem to be standardized criteria for such reports. Input from the mines is apparently used by higher management officials in analyzing trends and shaping the safety program, and it triggers inquiries from higher management to local mine management.

Union and management appear highly coordinated and cooperative in safety matters. MSHA is perceived, depending on the personality of particular inspectors, as enforcement-oriented. However, the consensus of local mine management seems to be that most of the regulations presently in force are directly related to safety and health.

At least one employee with emergency medical training is available on each shift. The nearest hospital facility is no more than 5 miles away, and an emergency medical squad with an ambulance is about a mile away. There is no light duty program after an injury. The return to work after an injury is a matter of medical clearance, usually from the employee's own physician. Absenteeism is low.

General Impressions at Mine D2

Morale is not as high and the esprit is not as well developed at Mine D2 as at D1. Miners voiced satisfaction with present mine management but indicated that there had been prior problems in labor relations and safety because of former supervisory officials. There remains an undertone of hostility and a greater readiness to voice complaints in a critical manner. This dissatisfaction is tempered only by a willingness to wait and see what the relatively new mine management will do and how it will conduct itself. The miners we interviewed believe that channels of communication were open, that they had access to all levels of mine management if there was a problem, and that mine management would be responsive to legitimate concerns.

Factors Contributing to Conditions at Mine D2

The imponderable factor here is the changing circumstances over the past few years. Poor relations between miners and mine management had existed until the past year or so. Present management adheres to all the policies and procedures in effect at Mine D1, but the supervisory cadre seems on the whole younger, and somewhat less experienced. Mine management recognizes the value of open communications and seems committed to achieving a high level of morale and cooperation. They perceive labor relations as good.

The history of the workforce at the mine further complicates the problem of drawing any conclusions. Prior to 1978 there were about 600 employees, in 1979 the workforce reached a low of about 80 people, and presently it is about 150. According to management personnel, in 1980, during a period when the number of employees was low (around 80), there were between five and seven lost time injuries. To date in 1981, there have been no more than three lost time injuries with a workforce that has grown to around 150 on two operating shifts.

A point also made by mine management is that statistical comparisons between pre- and post-1978 periods are uncertain because of changes by MSHA in reporting requirements.

Specific Information on Mine D2

The team observed roof control provisions in the mine. The travelways had additional support and were lined with a concretelike substance. Except at the face, the roof was supported by combination bolts. These had a 4-ft resin bolt above the standard bolt.

Union safety committeemen are elected for terms of two years. The role of the union safety committee was described in much the same terms as for Mine D1, but with a slightly different tone. There was an impression from the miners interviewed that the safety committee here is regarded as more necessary than is the safety committee at Mine D1.

Union-management relations at this mine seem more strained, with an undercurrent of cynicism on the part of some rank and file workers interviewed. However, this mine may suffer by comparison with the atmosphere in Mine D1. On the surface, every person interviewed assured the team that labor-management relations were good.

The medical facilities are generally the same as at Mine D1. The policy governing the return to work after injuries is the same as at Mine D1, but mine management indicated that younger miners may have had a disproportionate number of one-day absences, at least in 1978-79. Absenteeism is average for the area.

VISIT TO MINE E BY ZEGEER, DAMBERGER, AND LEWIS, JULY 29, 1981

In 1980 Mine E produced approximately 990,000 tons, up from about 640,000 tons the year before. It has nine active sections and runs 21 shifts per day. The method is standard room-and-pillar mining, with pillaring throughout the mine and the use of continuous miners. The company has 320 hourly workers and 75 salaried employees. About 300 workers are normally underground. The mine had an injury rate (degrees 1-5) of 1.8 in 1980.

Our contacts during the visit included the mine superintendent, the chief engineer, the supervisor of industrial and employment relations, an engineer, the mine foreman, and the safety coordinator.

Technical Information

The seam is about 4.5 to 5 ft thick; the mining height generally is 5 to 6 ft. About 50 percent (by weight) of the raw coal is rejected in the cleaning plant. Clean coal specifications are 0.75 percent sulfur, 10 to 10.5 percent ash, and 30 percent volatile matter.

There are only 12 to 15 more years of coal reserves at the present rate of production. To the northwest a sandstone parting divides the seam and renders it unminable where thicker than about 1.5 ft. If the price of coal is high enough 12 to 15 years from now, the company may be able to recover one of the two splits that are significantly thinner (and thus more expensive to mine) than the whole seam being mined.

Roof conditions pose a major problem. However, with roof control procedures the company has been able to cope with the difficult roof conditions. It operates some roof-bolting machines with automated temporary roof support and is trying to retrofit all other bolting machines. Four-ft resin bolts on 4-ft centers plus truss bolting are used. The truss bolts are used in addition to regular resin bolts and have greatly reduced roof failures.

The company keeps track on a map of unintentional roof falls. There is no particular maintenance shift so maintenance is performed when it is required. There are no bonuses or incentives for production. Between 250,000 and 300,000 cu ft of methane is liberated per day. The mine might be called gassy, but this is not considered a problem.

Labor-Management Relations

Our view was shaped by our contact with the mine's management. It was not convenient for us to talk to any workers. The relations between management and workers seem more formal than at the other mines we visited, though not strained enough to call them adversarial.

The mine superintendent said that labor-management relations were good and that there had not been a strike for four years. The workforce has been quite stable, especially during the past two years. The absentee rate is about 7 percent. The company has a clearly defined absentee policy. If an employee misses 10 percent of a month's work, he gets a letter. Repeated absenteeism can lead to suspension. There is no strong conviction that absenteeism is a major cause of injuries. General inside labor is used to cover absentee positions.

The mine superintendent talked about workers being better educated. He feels that there is no correlation between safety and age; the main factor is willingness to be trained. The company employs from a miner training program at a community college.

Safety

A safe working instruction booklet is used for 90 to 95 percent of training. The training program is under the direction of the safety coordinator, who has two safety inspectors working with him. New employees have to go through the company's standard training, and records are kept of the type of training an employee has received.

All employees are listed with their qualifications. Information is stored in a computer and is updated regularly. A miner needs at least eight hours per year of safety training for each qualification. If this training is missed, the miner needs to go through the full training program again and pass the tests.

Much of the training is conducted by foremen and entered on a file card. Foremen use four different cards, one each for shuttle car operator, scoop operator, continuous miner operator, and roof bolter operator. The cards show foremen who can operate equipment and when they were trained. Records of safety meetings are also kept on these cards by the foremen. Every three months the cards are pulled by the safety coordinator to update his file.

The company has a film library and films are sometimes shown. The subject is selected on the basis of recent experience. For instance, recently there was an eye injury; hence an eye injury film was shown to all workers. Certain areas have to be covered regularly, such as roof and rib control and ventilation. Safety films help break the monotony, but hands-on demonstration is preferred by the safety coordinator.

The company has two safety inspectors who inspect the mines daily. They make written reports that go through the safety coordinator to the mine superintendent.

Once a month the superintendent has a scheduled meeting with the union safety committee, but the committee may come to him any time in between. When unsafe conditions are identified by workers, the problem is normally taken care of by the foreman. Only in case of disagreement does the mine superintendent get involved.

A worker can be dismissed for walking under an unsupported roof. The union supports this policy. Disciplinary action for other unsafe acts is also standard procedure for both miners and salaried workers.

Since 1967 there have been four fatalities, the last one in 1977 from a roof fall in a pillaring section. All four fatalities were due to roof falls. Over the last several years management has emphasized reducing accidents at and near the face. Near misses that could have seriously injured somebody are examined, and management responds to them by modifying the safety training program. Management has not noticed that younger miners are more accident-prone. It feels that attitude of young miners is much more important to safety than their age.

During 1980 the company had 400 to 450 man-shifts accompanied by inspectors. The mine superintendent does not believe that citing a company for violations improves safety. He feels the emphasis should be more on job training, and management has noticed a trend in this direction lately. He believes that inspectors are under pressure to write citations. The mine has, however, had inspections without receiving citations.

The safety coordinator has had emergency medical training. In addition, workers trained in first aid are on every section. The hospital is a 20-minute drive away.

Visit to the Mine

Resin bolts 4 and sometimes 6 ft long are used at 4-ft centers. In addition, there are trusses every 4 ft. About 3 ft from the pillar, 45-degree angled holes are drilled 8 ft deep over the pillar. Resin anchor bolts are connected by the trusses. The layout calls for 18-ft-wide entries and crosscuts at 100-ft by 100-ft centers.

At the active section a major "roll" of sandstone cuts at an angle across the rooms and entries. Here the sandstone is in direct contact with the coal over a width of 300 to 400 ft and a length of at least several thousand feet. We observed roof bolting in this sandstone. Some layers of the sandstone apparently are particularly hard and difficult to drill.

The Fletcher roof bolter is equipped with large canopies for bolter operators. The bolters stand under this canopy while drilling. Under this kind of roof it is important for the roof bolter to be protected by a strong canopy.

VISIT TO MINE F BY DAMBERGER, LEWIS, AND ZEGEER, JULY 27, 1981

The company operated eight mines, most of which have a single operating section. In 1969 the company decided to become larger; it felt that this was the only way to meet the new safety requirements. In 1973 there were only 217 employees and an output of 400,000 tons. By 1978, 800 employees produced 1,500,000 tons. There was a decline in 1979 to 600 workers and 923,000 tons, but in 1981 employment was 800 and a production of 1,500,000 tons was expected. The company reported no lost time accidents in 1980. Our contacts during the visit were the president, who owns the company, the general superintendent, and the safety director.

Technical Information

Two different coal seams are mined. The first is about 4.5 ft thick, with a 1- to 25-in. thick parting in the middle. The clean coal has a sulfur content of 1.4 percent. The second seam yields coal with a sulfur content of 0.8 percent after 40 percent reject.

Continuous miners and room-and-pillar mining are employed. There are oil and gas wells drilled throughout the area, many of which are uncharted and unknown. These wells have metal casings and may introduce gas into the mine workings, so it is dangerous to mine into them.

The roof control plan calls for mechanical bolts of 3-ft minimum length on 4-ft centers. Roof failures are not a serious problem, according to the general superintendent. During pillar recovery there have been premature roof failures occasionally.

Labor-Management Relations

This company is nonunion. Labor-management relations appear to be good. The last strike was in the 1960s. The company plans its absenteeism. Workers earn 1 hour of vacation for every 10 hours of work, so the company plans to have 10 percent of its workforce absent each day. Working overtime lengthens the vacation time, though double shifting is discouraged.

The company teaches every man on a section every job, so that the men can substitute for each other. Different jobs have different rates of pay, and if a worker changes jobs for a whole day he receives the rate for the current job for that day.

The company is self-insured; an injured worker can receive 80 percent of his normal wage. The health insurance extends for 30 days after a miner is laid off and for six months after a miner is disabled.

Safety

The company has 15 operating sections in eight mines. The general superintendent is unaware of any significant differences in the safety records of his mines. He says that the major cause of injuries in the mines is moving and handling equipment. In 1972 there were two fatalities from rib falls. Recently there was one fatality by electrocution.

The general superintendent believes that continuity of management and employees contributes more than anything else to mine safety. When they open new mines they use older supervisors with new people. He believes safe mines are productive; one of their rules is "don't rush." His managers try to convince workers that there is no excuse for going out under an unsupported roof. There are no quotas for production, nor are there comparisons or competition between shifts.

The company follows MSHA regulations with respect to training. New hirees get the required initial 40 hours of training followed by 8 hours on the job. The required retraining is done for two hours per quarter before or after a shift, at company expense.

Accidents are reported on a standard form. The philosophy is that everyone in management is an inspector. If unsafe conditions exist, everyone is encouraged to call either the safety director or the general superintendent.

There are ambulances at the two main mines. Personnel trained in first aid are on every section. There is also a first aid station on every section. Emergency medical technicians manage the supply yard and are thus quickly available. The mines are 15 to 40 minutes from a local hospital. More severe injuries are taken to a hospital two to three hours away.

Visit to the Mine

The president of the company and the general superintendent accompanied us on the underground trip. Battery-driven cars are used for the mantrips. The entries are 20 ft wide and there are crosscuts on 60-ft centers. Roof control comes primarily from 48-in. bolts. Where the roof is shale some 60-in. bolts are used. A massive sandstone makes for an excellent, very stable roof. During our visit we saw no indications of roof problems. Safety problems with the roof arise during pillar recovery. About 40 percent of the coal is mined going in, with an additional 45 percent sought during retreat. Pillar recovery is known to be dangerous; the company mines only with 100 ft or more of cover because the roof tends to be weak under less cover.

VISIT TO MINE G BY SPOKES, AUGUST 18, 1981

The mine has 540 employees and an annual production of 1,200,000 tons. It operates one longwall face (with a second being developed) and six continuous miner sections, with two production shifts and one maintenance shift each day. The mine had an injury rate (degrees 1-5) of 35 in 1980.

Primary interviews were with the manager and assistant manager of mine health and safety and with the director of training, all at the corporate level. Shorter interviews were held with the safety director, with the safety inspector, and with several underground union workers.

The absentee rate fluctuates with the hunting, fishing, and farming seasons, with a norm of about 25 percent. As many as five men in a day will claim an injury that cannot be verified by company doctors, according to safety officials. These men may go to other doctors (who will verify their injury) or merely take one of the sick days provided for in the union contract. The high absenteeism makes it difficult to preserve team integrity.

Safety Program

The state requires that any first aid or higher medical treatment be reported. Reports are prepared by section foremen and reviewed and acted on by the corporate safety officer, particularly when MSHA reports are required. The safety officer investigates all electrical accidents, all accidents resulting in broken bones, all roof falls, and others where judged appropriate.

The foreman's report is used by the safety office to prepare the state and MSHA reports. A copy of the report is placed in the victim's file. The mine's safety department corrects working procedures to prevent the recurrence of accidents.

Each mine safety office keeps an accident ledger from which the monthly accident report is prepared, and in which safety statistics can be detailed. It was noted from the total injury experience page of the ledger that of 22 foremen listed in January 1981 only 6 were still foremen in July.

The monthly reports are used mostly by safety department personnel. Copies are not sent to the mine foremen. There is a distinct impression that no one above the manager of mine health and safety is interested in seeing the reports. There is no systematic attempt to keep track of near misses.

The accident frequency rate (degrees 1-5) was 14 in 1978, 23 in 1979, 35 in 1980, and 32 for the first six months of 1981. During this period the ownership of the mine changed. There was a major expansion of the mine in 1980.

Each working place is inspected once a week by one of the four safety department inspectors for that mine. These inspectors rotate areas quarterly. Housekeeping was good, the roof was good, but the floor was very soft, being flooded in low spots because of aquifers at higher elevations.

Most workers observe safety regulations and wear the required safety equipment. At one time the company required the use of powered respirators on the longwall section, but the workers refused because of the weight and bulk in the difficult working conditions.

The foremen are responsible to management for safety in the section. There are weekly safety meetings. An attendance sheet is signed by the workers, then the foreman reads a topic sheet and discusses it with the crew.

Role of Management, Labor, and Government

While there appeared to be no policy of firing foremen with poor safety records, it was reported that a number had quit because of heavy criticism of their high accident frequencies. A new policy provides that any safety violation receive a reprimand if minor, a suspension if other people are endangered, and a firing if it is a second occurrence. This rule applies to both workers and foremen and to foremen who observe workers violating rules and do not discipline them.

The manager of mine health and safety was trained and worked as a mine inspector for the U.S. Bureau of Mines some years ago. Safety directors move up from the ranks of inspectors after two years' minimum experience and are sent to safety seminars. Some have a college background, two have associate degrees in safety, and others are attending the same associate program.

The safety program appears to be well planned, but the lack of involvement by top management is a weakness. Responsibility for safety rests with the manager of mine health and safety. The entire safety structure is divorced from the production structure, though it has the power to enforce safety matters.

When a worker is disciplined, the record is placed in his personnel file. No log is kept of disciplinary actions; thus there are no statistics on the number of disciplinary incidents.

The local UMW president appoints the members of the safety committee, which elects its own chairman. When a union member is disciplined for a safety violation, the union committee always defends him. Union members who report safety violations by other members are ostracized.

The attitude of the safety department is that federal inspections are important to the safety effort but that some regulations are misdirected. Apparently, there is a three-way tug-of-war between management, labor, and government in the safety program.

Roof Control

Each mine roof control plan is developed by the mine manager, the chief mining engineer, and the safety director. The mine roof shale is quite strong, although there is slaking with the high humidity. The control plan was based on successful boltings in old workings. The normal spacing of 5 ft can be reduced to as little as 3 ft by the section foreman, and the roof bolters have full authority to use extra support wherever they judge it to be needed.

All falls of the roof above the bolts must be reported to MSHA. Smaller falls are noted in the firebosses' record books. All falls are plotted on maps. The last fatality from a roof fall occurred six years ago. Rib falls are a much greater hazard.

Training

The corporation has a central training facility with classrooms, television cameras and screens, tape editing facilities, and laboratories. Initial MSHA training is given here, plus electricity and hydraulics instruction and mine rescue team training. At each mine there are underground classrooms with television playback facilities.

New workers spend 45 days underground in "familiarization" required by the union contract. It usually is spent in belt cleanup. The worker is then given job procedure training on the basic machines: miner, shuttle car, roof bolter. Most of this training is from MSHA films that have been edited and updated locally to conform to present practices. When a worker bids on a new position, an instructor from the training department spends from a few minutes to several weeks with him to be sure that he is capable.

Supervisors, in addition to the required 40-hour MSHA training, have 54 hours of fireboss instruction and a three-day course on management. Thereafter they attend weekly one-hour classes. In addition, most management and safety people complete emergency medical training. Any employee can take emergency medical training. The two corporation mine rescue teams compete to determine which will attend the national mine rescue contest. Recently, this company's team became national champions.

Every mine has its own ambulance and an array of emergency medical technicians. Injured workers are taken 40 miles to a doctors' clinic and, when required, another 20 miles to a community hospital. There they can be sent by helicopter to a major city 120 miles away.

Summary

The safety department and workers perceive the greatest weakness to be a tendency by foremen to let safety slide until an inspector finds a deficiency.

The state of labor-management relations is calm but cool, perhaps because the workers have not fully accepted the new owners. Another reason is that the turnover of workers has prevented the development of a workforce with good esprit.

Factors that might improve the situation are (1) better training of workers in specific skills, (2) a better inspection program, and (3) a new disciplinary policy. Moreover, a positive movement of top management into direct involvement with safety is needed.

VISIT TO MINE H BY WRIGHT, DEREAMER, AND ROSEN, SEPTEMBER 3, 1981

In 1980 this mine produced approximately 1.5 million tons while employing 845 people, 750 of whom worked underground. The injury incidence rate (degrees 1-5) was 21.7 in 1980.

The mine has 14 continuous miner sections. Nine were operating the day of the visit. A section crew consists of a foreman, two bolter operators and two helpers, one miner operator and one helper, one scoop operator, two shuttle car operators, and one mechanic. Production averages about 250 tons per section per shift. The overburden thickness is 90 to 600 ft. The clean coal averages 3.5 to 4 percent sulfur. The run-of-mine coal averages 6 to 7 percent sulfur.

The mine has a bad roof that is sensitive to moisture, so there is considerable spalling and flaking. One can see areas where much of the roof is sloughed away around the roof bolts. Eight-ft bolts are normally used, but in belt entries, in mains, and in submains 8-ft bolts are used along the ribs and 10-ft bolts are used in the center. Bolts are torqued to 120 to 150 ft-lb; then they bleed down to 90 to 100 ft-lb. Some become loose, and loose bolts are one of the items that lead to citations.

The people we talked with at the mine included the division manager of safety and training, the vice president of operations, the mine superintendent, the assistant mine superintendent, the general mine foreman, a section foreman, the preparation plant manager, the chairman of the safety committee, the vice chairman of the safety committee, and several other miners.

Meeting with Management Officials

The absentee rate at this mine is 15 to 16 percent, of which 8 to 9 percent represents problem cases. Management believes this is good by comparison with other mines. They report suspicious cases to the company compensation department, but realize that such cases are hard to prove. Doctors are part of the problem, according to the officials; if they were fair and responsible the situation would be better, officials believe.

When asked if the reports they make to MSHA help the company, managers said that the intent of MSHA regulations and reports was good initially, but that the way they are being implemented today is not helpful.

This mine has a full-time safety committee of seven miners, paid by the company, which has been in operation most of this year. All the other mines we visited had the part-time three-man committee required by the UMW contract, where the members are paid by the union. Hence this mine has attempted an innovation in the operations of their safety committee. This is a voluntary arrangement that can be terminated by the company or the miners at any time. After several months experience with it the vice president feels that it is not working well. The intent was to have the committee work full time inspecting the mine and reporting to the company existing or potential violations that might eventually be cited by federal inspectors. It was hoped that this would reduce the number of citations and also prevent accidents. His experience, however, has been otherwise; the committee is flooding the company with demands and is being unreasonable about corrective action, especially as to timing.

Safety Program

The company has a system in which foremen make safety contacts with their section members. There is also a safety accountability program by which each foreman is rated on the safety record of his section, the number of citations, and other factors. The MSHA system for reportable accidents is used internally by the company.

The manager of safety said that the company used to have a program of awards for safety whereby the miners would get jackets and other bonuses. The company abolished the system, which the miners appeared to resent. The injury rate went from about 12 to 26, so the program was reinstated.

Mine Visit

We descended a shaft about 250 ft to the seam level and proceeded by railway jeep approximately 1 to 2 miles to the working section. The railway and the main were well maintained and heavily rock-dusted except for the obvious weathering and scaling of the roof. In the working section we met the section foreman and observed the operation of a Jeffrey continuous miner and of a roof bolter with a single drill and operator. The operator is under a temporary roof support that he elevates hydraulically. Eight 8-ft conventional steel bolts are used. The bolt fastens a steel plate about 6 in. on a side and the bolts are on 4-ft centers.

On our way out of the mine we were shown a mine emergency car used solely for rescues and maintained in ready condition by the company. They have installed normal first aid equipment, including a stretcher and a resuscitator. The nearest hospital is 17 miles distant; there is a clinic somewhat closer. Severe cases would be picked up by helicopter and sent to a hospital. There are no paramedics in the mine, but foremen are expected to have emergency medical training.

After ascending the shaft we paid a visit to the preparation plant. Our tour was conducted by the preparation plant manager. The plant employs 57 workers, but it was idle during our visit. It incorporates standard machinery for cleaning, drying, and grading the coal. Almost the entire output is shipped to an electric company for steam generation.

Safety Committee

We met for two hours with five members of the mine safety committee. All of these men are miners between the ages of 25 and 40.

They attribute the recent severe increase in the injury rate in part to cancellation of the awards program. They felt that this program motivated the miners toward safety and was successful; they were bitter about its cancellation.

Federal inspectors are doing a good job, the safety committee felt. The inspectors are well trained, and the committee has learned from observing them in operation. The federal people play an important part in the mine's safety; accidents would triple if they were withdrawn, the committee members said.

Q. What can be done to make mines safer? A. In a word, education, so that miners have safer working habits and are aware of safety. Foremen also need periodic retraining.

Q. Why isn't this done? A. If safety gets in the way of production, safety goes.

Q. Is the committee being fair with the company? Are you giving them enough time to correct the items you report? A. Yes we are, but the company does not use enough men to make corrections. Management should hire more people to take care of these problems. The company is getting its money's worth in avoiding citations.

When we asked about the safety program it was our impression that the committeemen were not aware of the safety accountability program in much detail. When we started to describe it they recognized it and agreed that the program might work, but they said that the foremen would be the first ones to violate it.

They asked what main and section we had visited, and we indicated the locations on a map. They asked, "What did we think of the mine?" and we observed that it had compared well with other mines we had seen. They laughed and said, "You were given a powder-puff tour. That main and entry were rock-dusted two days ago in anticipation of a high-level visit. We could take you in areas of the mine that are so black you cannot see your hand in front of your face." They offered to take us on a guided tour of the mine, but we demurred owing to lack of time.

The committee needs better equipment, an anemometer to check air flow, methane detectors, and electrical fault detectors, they said. They felt that the company should supply these to the committee. They also feel that it is not fair for only foremen to have emergency medical training and that there should be a nurse and doctor on the premises.

Q. In view of all your comments, how does this mine compare with others you have worked in? A. It is the best.

Q. Then why are you so hard on management in this mine? A. Because we want to keep it that way.

Q. How is communication between you and mine management? A. Reasonably good.

Q. Do you have respect for anyone in management? A. Yes, we have respect for the mine superintendent.

Q. Then what is the problem? A. The problems are not going away until management learns to treat the miners as people rather than as metal tags. Also, they could do a better job of training. We have learned more from federal inspectors than from the company. We have heard that other safety committees have been sent to Beckley, West Virginia, for the two-week course on safety, and we would also like to be sent.

Q. Why don't you ask the company to send you? A. We don't think they would listen.

Q. Where have you been helpful to the company? A. The company asked us to help them support the automated temporary roof support system for roof bolting and we did this.

Q. You must realize that the company is not happy with the way the full-time safety committee is operating. Why do you think they agreed to have the committee? A. The company felt we would be patsies, that we would be in the company's pocket, but it did not turn out that way. The safety committee is really doing the job it is supposed to do; that is why the company is not happy.

Team's Final Observations

There is clearly an adversarial relationship between labor and management at this mine. The mine has poor roof conditions, so the outby areas do need considerable maintenance.

VISIT TO MINE I BY WRIGHT, DEREAMER, AND ROSEN, JULY 16, 1981

Mine I, which has been operating for 33 years, produces approximately 750,000 tons annually and employs an average of 250 people. Access to the mine is by horizontal entries from the outcrop. The height of the coal seam varies from 70 to 90 in. There are two mains (north and south) approximately 2 miles in length from the mine entry to the working faces. The mining method is room and pillar. Pillars are removed in a retreating operation. There are four continuous miner sections and one conventional section. The mine has an extra continuous miner that is kept in operating condition to be used in case of a breakdown. The mine had an injury rate (degrees 1-5) of 63.9 in 1980.

The people we met at the mine included the supervisor of safety, the director of safety, the division manager, the mine superintendent, the associate safety engineer, the safety committee chairman, and several foremen.

Accident Reporting and Statistics

One of the reasons for visiting Mine I was to try to find an explanation for the great disparity between the accident rate claimed by the company and that reported by MSHA. For 1980 MSHA reports an accident frequency rate of 63.9 for injuries of degrees 2-5 and a rate of 74.8 for total injuries, including fatalities and first aid cases (degrees 1-6). The company, using their own definitions of injuries, claims only one degree 2 (permanent disability) accident and a frequency rate of 0.40 for 1980. Mine personnel reported no lost time accidents (degree 3) for 1980, while MSHA reported 127 for the same period.

Mine management does not pay much attention to MSHA incidence rates, claiming that most of the lost time accidents reported to MSHA are really not "true" lost time accidents. If a worker does not report to work the day following an accident, someone from the safety department telephones the injured employee and may, depending on the circumstances, visit the employee at home. In those cases where the safety department decides that the employee could have worked, the case is not recorded by the company. It is, however, reported to MSHA as a lost time case.

Mine managers and safety personnel alike pointed out that the state's workman's compensation rates are so high, with no tax on the compensation payments and no to-and-from-work transportation costs, that the payments almost equal the workers' regular pay. This problem is exacerbated by local physicians, who often agree with the employees' claims that they are not able to work.

A supervisor stated that this mine has an absentee rate of 22 to 23 percent, which is high. The mine has recently begun a program to reduce this rate in accordance with the union contract. The supervisor stated that about 40 to 60 miners, out of a total of about 400 employees, cause trouble, initiate grievances, and are often absent.

The director of safety feels that the method being used to measure the coal mine's safety performance is not effective. A corporate committee has studied this problem and has recommended a system for reporting and recording work injuries that contains elements of the American National Standards Institute Code Z16.1 and the Record Keeping Requirements of the Occupational Safety and Health Administration (OSHA). Table 29 gives the injuries reported in Mine I for May 1981.

TABLE 29 Injuries in Mine I, May 1981

Type of Case	Number of Cases	Frequency Rate
Away from work	1	1.56
Restricted work	0	0
Medical treatment	7	10.92
First aid	52	81.12
Total OSHA rate	60	92.60

The safety director believes that the company and MSHA should use total injuries (including first aid cases) to compute their frequency rate.

Mine Management

The mine superintendent impressed us as an outspoken individual; he said that he regards all safety inspectors, state and federal, as "time wasters." He feels mines could do a better safety job without them. He seems to tolerate the union safety committee (elected by the membership for a three-year term), but it appears that he has few contacts with committee members on substantive safety issues. The superintendent's negative attitude regarding state and MSHA safety inspectors was echoed by mine foremen and a supervisor.

Union Safety Committees

This mine has a three-member union safety committee, as provided for in the contract between the union and management. Members are elected for a three-year term. The safety committee chairman has served for 18 years. The chairman said that he has enjoyed good relations with management and that he believes the company has a real commitment to safety. He believes also that the safety training program is effective.

When members of the safety committee spot a safety violation, they report it to the safety engineer, whose job it is to have it corrected. The committee chairman claimed that he could shut down the mine by ordering out the workers, but he has not done this. In fact, he has not gone underground in the past one and one half years to investigate a safety disagreement with a member of management (the chairman is a dispatcher who works in the aboveground mine office). He believes, however, that the MSHA and state inspectors do a good job.

Safety Personnel and Safety Programs

The mine visit team met with the corporate supervisor of safety, the director of safety, and the associate safety engineer. The director has a graduate degree in safety management. Both he and the associate safety engineer are certified emergency medical technicians and mine rescuers and have passed all the tests required of a mine foreman. The safety engineer makes periodic inspections of the mine, responds to members of the union safety committee, and works with MSHA and state safety inspectors.

According to the safety director, the company has done some job safety analysis. It did not appear, however, that the mine is committed to using it. Foremen were vague about who should be making the analysis, how it should be done, and what purposes it should fulfill.

The mine does have a formalized job observation program. Each foreman is required to make at least two "personal safety contacts" per month per employee. A card for each employee is maintained by the foreman on which he notes the date the observation was made. A few of these cards were examined. None of them listed an "unsafe practice."

The safety director was asked what the three most important factors in mine safety were. His answer:

1. A strong commitment on the part of company management toward safety.
2. An attitude of cooperation between various levels of management and labor on safety.

3. An established, well-ordered safety program.

Working Conditions (Housekeeping)

Coal dust is on the floor, shelves, walls, shower rooms, in shoes, clothing, machines, and equipment--it's everywhere. One foreman said, "This is a mine, you can expect poor housekeeping." Debris, discarded clothing, empty cartons, years of accumulated dust, grease, oil, etc., were found in the mine office, the maintenance shop, the mine entrance, and the yard. Housekeeping at this mine is poor.

According to the safety director, trips, slips, and falls account for a high number of accidents in the mines. Many of these accidents might be prevented by better lighting in the mine and by good housekeeping.

Roof Control

The original roof control plan was drawn up by the company engineering office along with certain supervisors. It is based on experience plus geological information from drill holes. This plan has to be approved by MSHA; after that it is reviewed every six months by mine management and MSHA personnel. Unintended roof falls reported to the state department of mines are falls above roof bolt anchorage and falls that interfere with ventilation. The locations of such falls are plotted on a map. Automated temporary roof supports are used on the roof bolters, with the controls located near the back of the bolting machine so that the operator is not only under a canopy but also behind permanent supports. When installing bolts, the miner stands under a canopy that also has protective pipes on the side to protect against rib rolls. General roof conditions appear to be good; pillar ribs, however, slough readily.

VISIT TO MINE J BY ZEGEER AND LEWIS, AUGUST 18, 1981

The company that owns and operates Mine J has two old slope mines and four new shaft mines that have been operating for three to four years. The vice president of engineering said that one of these was targeted as "the worst mine in the country." Because of this the company decided to institute a safety and accident reduction program and employed the vice president to develop the program. He began the program in 1980, he said, and within a year reduced the accident frequency rate substantially. The company has large reserves in the area and has built impressive office and training facilities. They lease the surface to another company for strip mining.

Interview with the Vice President of Engineering

The vice president said that he was hired because of his experience in mine safety. His job includes responsibility for safety, ventilation, roof control, planning, training, and industrial engineering. He says that the company's safety program is not new, that it uses established procedures. He determined which employees were having accidents and brought them outside for training. MSHA requirements for training were doubled and the emphasis was changed to the causes of accidents. He does not believe that there are accident-prone people; people can be trained to operate safely, he said. Workers are involved in looking at the problems and figuring out how to solve them.

A management health and safety committee was formed of the president of the mining division, the vice president of operations, and the vice president of engineering. They meet each quarter to review the program.

The company has good rapport with the union. The vice president of engineering deals with their safety committee and shares responsibility with them. He tells them that both sides must demonstrate their willingness to cooperate.

The company employs a larger number of women than do most mines--213 of 2,790 underground miners--because the mines are new. Injuries have been recorded by sex and the women have more injuries, but the vice president thinks that this is due to their working largely as general labor.

When asked about the relationship with MSHA and the possibility of MSHA giving more assistance, he said that it is illegal for inspectors to do this for coal mines. MSHA does have a division of technical assistance, and he was currently using it to help develop blasting plans. As the industry continues to grow, new laws may include an advisory capacity. He believes that the industry needs federal regulation. The states alone are inadequate, he said. For instance, this state has only four to five inspectors, who are low key and give no fines. The company has 15 inspectors plus dust samplers.

Most of the company's mine managers are young (in their 30s); only one is 55 years old. The attitude of the workforce is good and not militant, he said.

Interview with the Safety Director

The safety director presented a slide show on the company's health and safety program, which is well organized and well defined. There are once-a-week safety meetings, and the foremen make two observations per month and one individual contact per week. Each worker has a card that includes information on safety meetings, training, observations, and contacts; all of this goes into a computer. This is important also in lawsuits on workman's compensation.

The company is building its own clinic but now uses clinics 12 or 15 miles away. An ambulance is near enough to be present when someone is brought out of the mines. All safety inspectors, foremen, and dust samplers have been trained in CPR.

Visit to the Mine

The associate safety inspector, the mine manager, and the safety director accompanied us. The mine is 2,000 ft deep; it liberates 16,000,000 cu ft of methane per day. There are 12 sections. There is one safety inspector and two associates; one of them is present on each shift. There are about 600 underground workers. All sections use continuous mining, but a longwall is planned for next year. Sixty-three percent of the coal is recovered. Output averages 7 to 8 tons per worker per day. The mine had an injury rate (degrees 1-5) of 16.7 in 1980.

The mine manager said that he felt worker relationships--cooperation and team spirit--are the most important factors in safety, but this takes time to develop in a new mine and is hard to develop in large mines. There is a generation gap in the mines, he said, because the members of one generation did not work in the mines and so did not inherit knowledge of mining from their fathers.

The associate safety director said that accidents happen when people try to take shortcuts. Sometimes workers get too confident; for example, under a good roof, workers take chances.

VISIT TO MINE K BY WRIGHT, DEREAMER, AND ROSEN, SEPTEMBER 2, 1981

Total production in Mine K was approximately 1,000,000 tons in 1980. Its average employment is 430. The mine had an injury rate (degrees 1-5) of 43 in 1980.

The people we spoke with included the mine superintendent, the mine safety director, a dust and noise technician, two members of the mine safety committee, a section foreman, a roof bolter, and several other miners.

The company has nine continuous miner sections (with one spare continuous miner) and one shortwall section. They operate one of the continuous miners in a shortwall that has a panel width of 180 to 200 ft. The seam is 48 in. thick and has an average depth of 650 ft.

Coal is delivered directly by slope conveyor to an electric generating plant. There is a preparation plant at the power plant. Access to the workings for the miners is by elevator shaft, which we used; there is also a slope.

Safety Experience

During the first six months of 1981 there were 59 reportable accidents, for an injury incidence rate of 31.1. Lifting accidents accounted for 41 percent of these (29 percent "backs only" and 12 percent "all except backs"). During this same period there were 208 federal citations, of which 25 percent were "electrical" and 19 percent were "cleanup." There was one lost time accident attributed to "electrical shock, burns." The most serious accident during this period was a broken leg with an open fracture of the bone. Both this and one other fairly serious accident involved helpers who were fill-ins.

The safety director believes that there is a correlation between high injury rates, citations, and low production. In general, a section with a high injury rate also has a high number of citations and low production. The company's goal is an injury rate of 20.

The safety director is responsible for reporting injuries to MSHA, and he is worried about violating the federal statutes. If a man is absent one day and claims injury, the director reports it as a lost time accident but tries to verify that the injury is associated with the accident. He feels that there is a correlation between accidents and absenteeism that is strong at this mine.

The slots of absentees have to be filled by others not familiar with the conditions in a particular area.

The mine superintendent feels that the compensation pay is too liberal and acts as an incentive for workers to report injuries. Their absentee rate is about 16 percent, but that includes the contract vacation days. Through September 1981 it was 25 percent, including vacations. They had a high injury rate in March that the superintendent attributes to workers trying to get on compensation in anticipation of the end of the union contract.

The mine has had three roof falls recently, all under supported roofs. The roof tends to scale in this mine, which is a hazard the company must live with, according to the superintendent. It could be prevented by using mesh all through the mine, but that would be expensive. The shortwall area, which the safety director feels is inherently safer, has a lower injury rate.

The company uses job safety analysis. Each job has a description that is revised as necessary. When asked which, in his opinion, were the most important factors promoting safety, the superintendent listed (1) foremen working closely with the miners, (2) the safety director working closely with the miners, and (3) good communication.

Attitude Toward MSHA

Both the superintendent and the safety director are highly critical of the government's role. When asked how the government could do a better job, they responded, "They should talk to people instead of just writing citations. They should work with management and workers to improve safety, but they are not doing that now. Their job is to inspect and write citations." The superintendent feels that the inspectors are capable people and could work in a more cooperative role but that the law requires them to do otherwise. The state inspectors are more cooperative; they make inspections quarterly, spending two to three weeks at the mine, and give the superintendent a report on the mine. The superintendent feels that they are helpful and competent. The safety director feels that some of the federal regulations are out of date. A government project is under way to update mine safety regulations, and he is supplying data to it. Through July 1981 there had been 300 MSHA inspection shifts.

Company Safety Staff

The safety staff consists of the director and two assistants who monitor the entire safety program. They report and investigate all accidents and injuries. They make dust and noise measurements and report results to MSHA. They accompany MSHA and state inspectors on visits.

The company has an employee record system maintained by the foremen. This system provides for eight contacts per month for each man working underground. The eight contacts include one planned observation, four group contacts, two individual contacts, and one personal inspection.

Safety Committee

The safety committee consists of the chairman of the mine committee, who is a mechanic, another mechanic, and the safety committee chairman, who is a beltman. They feel that the injury rate for this mine is high, in part because of 20 to 25 chronic absentees. They feel that the compensation rate is too high and encourages men to stay off. The men on compensation receive all the benefits, and their payments are suspended while they are on compensation, so they view it as a good thing. The safety committeemen believe that there should be strict investigation of compensation cases by the state and by the insurance carriers. They resent the fact that workers who do not deserve compensation are receiving it, and they believe that 75 percent of the men would support their viewpoint.

Underground Visit

We entered the mine through the shaft and traveled most of the way through the mains on rubber-tired, battery-operated vehicles. The roof was relatively low, about 48 in. At the operating section we met the section foreman. He started work in the mine at 18 and has a total of 10 years' experience, 5 as a foreman. He is concerned about absenteeism; three of the men on his crew were absent that day, including the continuous miner operator. One of those absent had a bad back, another had a smashed finger, and the third, the continuous miner operator, was just taking the day off. He feels that most injuries are due to falls, strains, pinched fingers, and carelessness, which varies with the individual. Often men are not sufficiently alert, and sometimes seeing is difficult in the mine. Variations in roof height also cause difficulty. The solution is to make the equipment lighter and easier to handle, according to the foreman. He said that he has never been injured or taken a day off when he was needed.

Roof conditions vary from poor to fair. In some areas the bottom 18 to 24 in. of the roof cannot be held up, so it is mined along with the coal. Sectional bolts 6 ft long are doing a fair job of controlling the roof. The top 3-ft section consists of a reinforced resin bolt, and the lower 3 ft is a conventional section under tension, installed at 250 to 300 ft-lb of torque. Roof bolters with automated temporary roof supports are used.

APPENDIX A

OTHER SOURCES OF INFORMATION

During the study, committee members examined many publications, reports, documents, and current news articles dealing with coal mine safety. A list of the publications, not included in this report as specific references but made available to committee members as background information, is given below.

Arthur D. Little, Inc., Safety Analysis of Self-Contained Self Rescuers, Report submitted to the American Mining Congress by the Bituminous Coal Operators Association, A. D. Little, Inc., Cambridge, Massachusetts, November 1980.

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Ragsdale, Jim, "Mine Safety: Where to Go from Here?" Charleston, West Virginia, Gazette-Mail, January 18, 1981.

Shaw, C. T., "Personal Responsibility for Mine Safety," Mining Congress Journal, pp. 48-52, November 1980.

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South Wales Miners in America, Report of the First Rank and File British Miners' Delegation to Visit the U.S. Coalfields, South Wales Miners Library, Swansea, 1979.

United Mine Workers Journal, "Maryland Miners Risk Lives Daily," November 1980.

U.S. Bureau of Mines, Technical Highlights, Health and Safety Research Program 1970-1980, USBM TN295.U5, U.S. Department of the Interior, Washington, D.C., 1981.

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Washington Post, "Pilgrim Mine: A Legacy of Fear, Doubt," December 20, 1980.

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Washington Post, "The Sorrow at the Rushton Mine," June 24, 1981.

Zabetakis, M. G., Accident Prevention, MESA Safety Manual No. 4, U.S. Department of the Interior, Washington, D.C., 1977.

Zabetakis, M. G., Productivity and Safety in U.S. Bituminous Coal Mines, American Mining Congress, St. Louis, May 11, 1981.

Zabetakis, M. G., and Rankin, J. E., Accident Investigation, MSHA Safety Manual No. 10, U.S. Department of the Interior, Washington, D.C., 1978.

In addition, committee members read all or parts of over 100 reports of fatalities that occurred in 1979 in U.S. underground coal mines. Reports were obtained from the Mine Safety and Health Administration and from the United Mine Workers of America.

APPENDIX B

BRIEF BIOGRAPHIES OF COMMITTEE MEMBERS

ERNEST M. SPOKES is a professor of mining engineering at the University of Missouri. He has been an engineer and a manager in the industry and a consultant to government and industry. He is an expert on mineral and coal preparation, mining methods, mine safety, mine management, mine industry economics, mine systems analysis, and mining environments.

I. W. ABEL is a labor leader and a former steel mill worker. A pioneer in the struggle for unionization of the steel industry, he became president of the United Steelworkers of America, the third largest union in the United States. He is also known nationally for his efforts to promote safety in the steel industry.

HEINZ H. DAMBERGER is a geologist and head of the Coal Section, Illinois State Geological Survey, who has done research on coal geology and coal petrography, the classification of coal, the microstructure of coal, and geological parameters that control roof stability or roof failure in underground coal mines.

RUSSELL DeREAMER is an expert on industrial safety who has directed the safety programs at IBM and at General Electric Company. He was President of the American Society of Safety Engineers and is the author of two books, Modern Safety Practices and Modern Safety and Health Technology. He has given numerous lectures on safety in the United States and abroad.

ALAN R. DIMICK is a surgeon, a national authority on burn surgery, and Director of the burn unit at the University of Alabama hospitals in Birmingham, Alabama. Miners severely burned and injured in mine explosions and other accidents are brought to this unit for treatment.

STEPHEN W. LAGAKOS is Associate Professor of Biostatistics at the Harvard School of Public Health. He has carried out research in the planning, design, and analysis of cancer clinical trials and in environmental safety testing.

HELEN M. LEWIS is a sociologist who has been a professor and lecturer at the universities of Virginia, Kentucky, and East Tennessee State. She has done research for industry and government, including the U.S. Bureau of Mines. She has written extensively on sociological aspects of Appalachia and on the American coal miner and his relationship to society.

WILLIAM H. MIERNYK is Benedum Professor of Economics and Director of the Regional Research Institute at West Virginia University. He has been a lecturer at Harvard University and the Massachusetts Institute of Technology and a consultant to government and industry. His research has included applications of regional input-output methods to regional analysis and studies of the regional impacts of rising energy prices.

MORELL E. MULLINS is a professor in the School of Law at the University of Arkansas. He served for almost 10 years as an attorney for the U.S. Department of Labor, including two years as Associate Solicitor, Division of Mine Safety and Health, where he supervised a staff of 60 attorneys and clerical personnel in providing legal support for the Mine Safety and Health Administration. He was involved in developing and drafting the Mine Safety and Health Act of 1977.

GERALD I. SUSMAN is Professor of Organizational Behavior at the Pennsylvania State University. He has done research on the influence of job design and work group structure on work motivations, with respect, in particular, to underground coal mines. He was a principal investigator in the Rushton Quality-of-Work Experiment.

FREDERICK D. WRIGHT is a professor of mining engineering (recently retired) at the University of Kentucky. He has held managerial positions in mining in the United States, West Africa, and Mexico, was an engineer with the

U.S. Bureau of Mines, and is an expert on rock mechanics, strata control, design of underground structures, drilling, blasting, loading and transportation in mines, and operations research.

DAVID A. ZEGEER is a consultant and a mining engineer who retired as Manager of the Beth Elkhorn Division, Bethlehem Steel Corporation. He has published technical papers on many aspects of coal mining and has been recognized by professional organizations for his contributions to the mining industry. He is co-editor of a recently published textbook entitled Elements of Practical Coal Mining.