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Review of Recent Research on Organizational and Behavioral Factors Associated With Mine Safety

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	mt	metric ton
ft^3/min	cubic foot per minute	pct	percent
h	hour	st	short ton
min	minute	yr	year

REVIEW OF RECENT RESEARCH ON ORGANIZATIONAL AND BEHAVIORAL FACTORS ASSOCIATED WITH MINE SAFETY

By Robert H. Peters[1]

ABSTRACT

This report presents a literature review conducted by the U.S. Bureau of Mines. The review summarizes what has been learned from recent empirical studies of the relationship between mine safety and characteristics of miners, mine management, and mining companies. The review is based on literature published in the United States during the period from 1976 to 1988. In addition to summarizing the empirical findings, this report discusses the implications and limitations of these studies, and gives recommendations for improving mine safety. An annotated bibliography section appears in the appendix.

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INTRODUCTION

Research on organizational and behavioral factors in the mining industry represents a promising approach to the improvement of miners' safety. Such research projects are usually very expensive and often require several years to perform. Because they are so costly, it is important that researchers begin their studies by reviewing any work that has already been performed. Learning what others have done improves their understanding of the problem and their ability to design an effective study.

The purpose of this U.S. Bureau of Mines report is to provide researchers and mining industry officials with a review of the recent United States research literature concerning the relationship between mine safety and characteristics of miners, mine management, and mining companies. Using computer literature search services, it was found that 17 empirical studies on this topic had been published in the United States during the years 1976 through 1988. For a review of the foreign literature on this topic, see Peters (*23*).[2]

The body of this report is organized into three major sections. The first section reviews the research findings concerning 16 company-level variables; three variables concerning the amount of control employees have over what happens on the job, three variables related to management-labor relations, four variables related to supervisor-employee interactions, and six variables pertaining to individual miners. The second section presents an overview of the findings, and makes some statements concerning the use of caution in interpreting the findings given the nature of the experimental designs and research methods that were used in most of these studies. The third section presents recommendations about improving mine safety that were given by the authors of the 17 studies reviewed in this report. This report also contains an appendix, which gives the following information about each of the 17 studies: the references for publications concerning the study, the study's objective, the methods used to perform the study (including a brief description of experimental interventions and data analysis procedures), the results, and (where applicable) major conclusions.

REVIEW OF RESEARCH FINDINGS

Table 1 lists the studies included in this review and indicates the following about each: the experimental design, the type of ore mined, whether surface or underground, the number of mines or companies from which data were collected, and the manner in which mine safety was measured.

The experimental design. The studies that look for naturally occurring relationships between variables and measures of mine safety by collecting data at only one point in time are labeled correlational. One study used a cross-lag panel design (*27*). Data were collected at two points in time, and the effect of changes in the correlates on changes in safety measures were examined. This is a relatively good design because it allows one to make better inferences about the direction of causality. In the correlational and cross-lag panel studies, the effects of planned changes on mine safety were not studied. Other studies, labeled interventions, involve observing the effects of some planned change (e.g., a new training program) on indexes of mine safety. Measures of mine safety are taken before and after the intervention is introduced, and inferences are made about the role of the intervention in producing observed changes in safety. Unfortunately, given the frequent lack of adequate control sites, and the complexity of the interventions, it is often quite difficult to determine precisely what was responsible for the observed improvements in safety. In instances where control sites are used, this design allows one to make relatively strong inferences about the existence of causal relationships between variables.

A technique often used in performing research on company-level determinants of employee safety is to look for factors that differentiate between companies that have established records of good versus poor safety performance (*7*). This type of study is labeled the contrast design. Typically, data are collected on a very large number of factors, and statistical tests are performed to see which factors differentiate between the two groups of companies at a statistically significant level. There are some important limitations to this type of study: (1) When considering a large number of factors, one should expect to observe a certain number of statistically significant relationships between variables that, in reality, are not related to one another; (2) one cannot specify the direction of causality, or the extent to which two variables are influencing each other in a reciprocal manner; (3) one cannot rule out the possibility that the observed relationship might be because of the influence of some unmeasured variable that is highly correlated with the ones measured. In other words, it may be the case that the measured variable is not the true cause of differences in safety performance; rather, the true cause influences both safety performance and the variable found to be correlated with safety performance.

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

Table 1.–Description of empirical studies of organizational and behavioral factors affecting mine safety (1976-1988)

Investigator and reference	Design	Mine type	Sample size	Safety index
Althouse (*1*)	Contrast	Underground coal	29 mines	Not available.
Bell (*3*)	Intervention	Underground silver	1 mine	Lost time.
Bennett (*4*)	Correlational	Underground coal	All U.S. coal	Lost time, non-lost time.[1]
DeMichiei (*9*)	Contrast	.. do	40 mines	Not available.
Edwards (*10*)	Intervention	Surface coal	1 mine	All.
Fiedler (*12*)	.. do	Underground trona	.. do	All, violations.
Gaertner (*14*)	Correlational	Underground coal	10 companies	Do.
Goodman (*16*)	Intervention	.. do	1 mine	All, violations.[2]
Goodman (*17*)	.. do	.. do	4 mines	Lost time.
Goodman (*18*)	Correlational	.. do	5 mines	All.
NAS (*21*):				
1st data set	.. do	.. do	All U.S. coal	Multiple.[3]
2d data set	.. do	.. do	19 companies	Do.[3]
3d data set	Contrast	.. do	12 mines	Lost time.
Peters (*24*)	Intervention	Surface gold	1 mine	All, hazards.
Do	.. do	Surface coal	2 mines	Do.
Do	.. do	Underground coal	.. do	Do.
Pfeifer (*25*)	Contrast	.. do	28 mines	Not available.
Rhoton (*26*)	Intervention	.. do	1 mine	Hazards.
Sanders (*27*)	Cross-lag panel	.. do	22 mines	Lost time.
Uslan (*30*)	Intervention	Underground salt	4 mines	Selected.[4]
Wagner (*31*)	Correlational	Surface iron	10 mines	Days lost.

NAS National Academy of Sciences.
[1]Dependent variable was a dichotomous indicator of whether the injury was considered a lost-time or non-lost-time incident.
[2]Five measures from Government safety inspectors were used: total MSHA violations per section, total State violations per section, number of times section was closed down, quarterly global ratings of section safety by Federal inspectors, and quarterly global ratings of section safety by State inspectors.
[3]Rates for several categories of injuries and accidents were computed, including fatalities, lost-time incidents, non-lost-time incidents, and serious incidents.
[4]Total number of eye, head, hand, and back injuries per month.

Safety indexes. The most commonly used measure of mine safety is the rate of lost-time injuries reported to the Mine Safety and Health Administration (MSHA) per 200,000 employee hours of exposure. Some studies used the rate of total injuries reported to MSHA per 200,000 employee hours of exposure. This measure is designated by "all". Some critics argue that the lost-time injury rate is a more valid index for assessing differences in safety performance than the "all" injury rate because there could be significant variations in the extent to which mine operators actually report non-lost-time injuries to MSHA. Some studies have defined the measure of safety more narrowly, and have used the rate of injuries to selected body parts, etc. Another measure of safety commonly used is the severity of the injury. Severity is operationally defined as the number of workdays missed following the injury.[3] Another measure of safety is the number of violations issued by mine inspectors. Finally, some studies have defined safety in terms of the number of hazardous conditions or instances of unsafe work practices observed during periodic inspections of the worksite.

Except for the studies by Edwards (*10*), Goodman (*15-18*), Peters (*24*), and Uslan (*30*), all these studies used data provided by MSHA to compute rates of accidents, injuries, and violations, and to define injury severity. Severity is usually defined as the number of days away from work following the injury. With the exception of the studies by Bennett (*4*), Edwards (*10*), and Rhoton (*26*), all the studies were funded by agencies of the U.S. Government, primarily the Bureau.

Table 2 lists the organizational and behavioral variables that have been found related to some measure of mine safety at the probability (p) < 0.05 level of statistical significance. Positive relationships to mine safety should be interpreted as: increases in variable X (or the presence or use of X) are associated with a better safety record. Negative relationships to mine safety should be interpreted as: increases in variable X (or the presence or use of X) are associated with a poorer safety record. The variables are organized into five categories: organizational, employee control, management-labor relations, supervisor-employee interaction, and individual miner. The empirical evidence concerning each of the variables listed in table 2 is discussed in the following pages.

[3]Although none of the studies in this review used it, another potentially useful measure of accident severity would be an index that normalizes the number of workdays lost by the number of hours worked, e.g., number of lost workdays per 200,000 employee hours.

Table 2.–Summary of organizational and behavioral variables associated with mine safety

Variable	Investigator and reference	Association direction
Organization:		
Training for miners	DeMichiei (*9*)	Positive.
Do	Pfeifer (*25*)	Do.
Training for managers and supervisors	Fiedler (*12*)	Do.[1]
Do	Peters (*24*)	Do.[1]
Do	Uslan (*30*)	Do.[1]
Management planning	DeMichiei (*9*)	Do.
Management commitment to safety	.. do	Do.
Do	Pfeifer (*25*)	Do.
Production competition between crews	.. do	Negative.
Production pressure	.. do	Do.
Do	Sanders (*27*)	Do.
Equipment availability	DeMichiei (*9*)	Positive.
Safety & health equipment maintenance	Pfeifer (*25*)	Do.
Safety-production incentive program	Gaertner (*14*)	Do.
Safety disciplinary actions	.. do	Do.
Size of mine	NAS (*21*)	Do.
Feedback and praise	Rhoton (*26*)	Do.[1]
Night shiftwork	Wagner (*31*)	Negative.[2]
Employee control:		
Worker participation in problem solving	Edwards (*10*)	Positive.[1]
Do	Bell (*3*)	Do.[1]
Do	DeMichiei (*9*)	Do.
Worker autonomy	Goodman (*16*)	Do.[1]
Do	Sanders (*27*)	Do.
Decentralized decisionmaking	DeMichiei (*9*)	Do.
Management-labor relations:		
Overall labor relations climate	Gaertner (*14*)	Do.
Management concern for labor	DeMichiei (*9*)	Do.
Do	Pfeifer (*25*)	Do.
Labor support for safety discipline	DeMichiei (*9*)	Do.
Supervisor-employee interaction:		
Reporting hazards to supervisor	Pfeifer (*25*)	Do.
Employee development	Sanders (*27*)	Do.
Praise for working safe	Pfeifer (*25*)	Do.
Do	Uslan (*30*)	Do.
Communications to miners	DeMichiei (*9*)	Do.
Individual miner:		
Absenteeism	Goodman (*18*)	Negative.
Do	DeMichiei (*9*)	Do.
Do	Pfeifer (*25*)	Do.
Coworker relations	.. do	Positive.
Role ambiguity	.. do	Negative.
Do	Althouse (*1*)	Positive.
Role overload	Pfeifer (*25*)	Negative.
Role conflict	.. do	Do.
Do	Sanders (*27*)	Do.
Age	NAS (*21*)	Positive.

[1]Variable was only one of several changes introduced more or less simultaneously as part of a complex organizational intervention. It is not clear how much, if any, of the observed effects on safety should be attributed to this variable.
[2]Accidents experienced on night shift are more severe than those experienced on day or afternoon shifts.

ORGANIZATIONAL FACTORS

This category of variables includes factors other than management-labor relations that characterize or that affect the entire mining operation or company, such as the size of the operation, management's emphasis on achieving various objectives, use of safety policies and practices, company-wide training programs, etc. These variables describe organizational level characteristics (as opposed to characteristics of individuals or workgroups within the organization) that have been examined in studies of mine safety performance.

Training for Miners

DeMichiei (*9*) made the following observations of significant differences in the mean responses of mine managers and safety officials from high- versus low-accident rate mines: (a) new miners in high-accident rate mines were less informed on how to do their jobs than new miners in low-accident rate mines, (b) supervisors at high-accident rate mines did not provide the same degree of instruction and guidance to miners as did supervisors in low-accident rate mines.

Pfeifer (*25*) made the following observations of significant differences in the mean responses of miners from high- versus low-accident rate mines: (a) there is a consistent tendency for training on various topics to be rated as better by underground miners at low-accident mines, (b) good training in how the electrical power system works, dealing with hazards (such as gases, coal dust, and noise), and how to use tools and equipment is more prevalent in mines with lower accident rates, and (c) lack of training in the proper use of safety and health equipment was more frequently cited as being an important reason for not using the equipment by miners at high-accident mines.

Training for Managers and Supervisors

A major focus of three intervention studies that produced significant improvements in safety was the provision of training for managers and supervisors. Fiedler (*11*) used a training intervention called the Leader Match program. This program teaches individuals to diagnose their own leadership styles, as well as to diagnose the leadership situations. The leaders are given detailed instruction on various methods for modifying the situations to match their particular management approaches and personalities. The instruction is provided by a trainer, who uses a detailed manual, aided by videotaped illustrations, slides, and/or transparencies. Videotaped vignettes in actual and staged settings were used to teach supervisors how to deal with specific problems with employees including: reinforcing safe behavior, correcting an employee, overcoming resistance to change, handling an irate employee, and creating a cooperative workteam.

The training intervention reported by Peters (*24*) entailed (a) conducting 8 h of training for subordinate managers and supervisors in loss-control fundamentals; (b) providing 8 h of training to supervisors and workers selected by the top manager in the use of an accident investigation methodology developed by the Bureau; and (c) furnishing available materials for training mobile equipment operators and assisting in task training course development.

The training intervention reported by Uslan (*30*) was called positive motivational safety training (POMOST). This training provides supervisors with "an understanding about behavior and a process by which they can improve performance; increase safe work behaviors, help the employee feel better about himself, the company, and his job; and generally establish a work environment which is positively supportive." The principal reinforcer used in POMOST is praise, i.e., positive verbal feedback. POMOST instructs trainees how and when to praise their employees. The program was taught in 22 to 40 h, depending on need. The program objectives were as follows:

How to recognize unsafe behaviors.

How to develop behavior baselines.

How to determine what behaviors to change.

How to communicate behavior change to employees.

How to shape behaviors.

How to maintain a safe work behavior program.

This training discourages the use of punishment. Rather, emphasis is placed on the first line supervisor focusing the employees' attention on the appropriateness of their behavior. The existence of inappropriate behavior is not ignored, but perceived as a training problem.

Approximately 100 managers and supervisors from four plants were trained in the use of positive reinforcement for occurrences of safe behavior. Each supervisor was also provided manuals and other supportive materials. Additionally, following training, all supervisors were provided some coaching experience to keep the knowledge and capabilities gained during training from being lost.

Management Planning

DeMichiei's (*9*) questionnaire results suggest that in comparison with low-accident rate mines, there was a greater tendency for management to put off making important decisions and more worktime was lost through poor scheduling and planning at high-accident mines.

Management Commitment to Safety

Pfeifer's (*25*) questionnaire data suggest that in comparison with miners in high-accident mines, miners in low-accident mines felt that keeping good safety records and upholding the company safety record were significantly more important to their companies.

DeMichiei's (*9*) questionnaire results suggest that management at high-accident rate mines provided less support for decisions made by section supervisors concerning safety than did management at low-accident rate mines.

DeMichiei (*9*) makes the following observations regarding information provided to him through interviews with mine managers and safety officials: (a) in five high-accident rate mines, the mine superintendents had no direct involvement in the mine's safety and health program; (b) responsibility for implementing the program was mainly the safety department's; and (c) safety department personnel at these five high-rate mines identified the lack of upper management involvement in safety matters as a serious impediment to improving safety and health conditions at the mine.

Production Competition Between Crews

Pfeifer's (*25*) questionnaire results suggest that in comparison with miners in high-accident mines, miners in low-accident mines felt that having competition among work-crews was significantly less important to their companies.

Production Pressure

Pfeifer's (*25*) study suggests that in comparison with supervisors in high-accident mines, supervisors in low-accident mines are significantly less inclined to push hard for production or to cut corners on safety.

Sanders' (*27*) findings, based on a cross-lagged panel design, suggest that a causal relationship exists between increased levels of production pressure and increases in the rate of lost-time injuries. Sanders states, "Production pressure appears to lead to an increase in disabling injuries which in turn results in a decrease in production pressure."

Equipment Availability

DeMichiei's (*9*) questionnaire study suggests that miners in low-accident rate mines are better provided with supplies, equipment, and the tools necessary for job accomplishment than are miners at high-accident rate mines.

Safety and Health Equipment Maintenance

Pfeifer's (*25*) questionnaire results indicate that miners in low-accident rate mines cite poor maintenance of health and safety equipment as being an important reason for not using it significantly more often than miners in high-accident rate mines.

Safety-Production Incentive Program

Although the specific terms of combined safety-production incentive plans vary, they all have the same basic structure. These plans pay out some form of bonus for production above a specified target, provided the number of accidents does not exceed some specified maximum number. If more than the maximum number of accidents occur, then bonuses are not paid for exceeding the production target, or the amount of the bonus is reduced according to some predetermined formula.

Gaertner (*14*) compared coal companies using a combined safety-production incentive program with companies not using such a program. He found that the average rate of lost-time injuries was lower for the companies that were using the combined safety-production incentive program. Likewise, Page (*22*) performed a case study of the characteristics common to high producing underground coal mines and found that 18 out of 25 of them had some form of combined safety-production incentive program.

Gaertner (*14*) also compared coal companies using an incentive program based on safety performance alone with companies that had no type of incentive program, and found that the average rate of injuries was essentially the same for the two groups of companies. Likewise, Goodman (*17*) found that the rate of accidents was NOT significantly affected by the introduction of a safety incentive program at any of the four different coal mines included in the study.

The reasons for the observed difference in safety performance between companies using combined safety-production incentive programs versus those using an incentive program based on safety performance alone are not entirely clear. Gaertner offers the following speculation concerning his results:

> Safety incentives not tied to production tended to be relatively inexpensive and symbolic (T-shirts, caps, decals) and generally did not indicate a serious commitment by management to safety in the eyes of the foremen and hourly employees. Rather they were usually intended as "reminders to the men, to keep thinking about safety," as one manager put it. Combined production-safety incentives seem more effective, and generally more costly. In one company, the cost of the production-safety incentives was 25 cents per ton; in another it was 81 cents per ton. As one foreman put it, the incentive program in place in his company "made management put their money where their mouth was."

Safety Disciplinary Actions

Some coal companies have (and use) disciplinary actions applied to safety violations by miners and supervisors. Gaertner (*14*) compared companies using such a policy with companies not using such a policy, and found that the rate of injuries was lower at companies that used a safety discipline policy.

In Braithwaite's (*5*) case study of the five major coal companies with the best safety records during the early 1980's, he notes that there was considerable variation in their use of punitive actions for violation of safety policies. Two of the five companies used punitive measures much more often than the other three.

Size of Mine

The National Academy of Sciences (*21*) analyzed MSHA's data concerning all lost time injuries that occurred in U.S. underground coal mines during the 3-yr period 1978 through 1980; such injuries numbered nearly 40,000, including fatalities. One of the variables, which emerged as highly correlated with rate of fatalities, was mine size. It was found that the fatality rate for mines with 50 or fewer employees (0.14) was about three times that of mines with over 250 employees (0.05), and almost twice that of mines with 51-250 employees. Small mines (< 50) accounted for 15 pct of total employee-hours, but 40 pct of all fatalities.

Feedback and Praise

Rhoton (*26*) was successful in virtually eliminating MSHA ventilation violation notices at a coal mine that, prior to the intervention, had been experiencing an average of 2.6 such violations per month. The intervention was conducted by the company's safety inspector, and consisted of: praising face crews and their supervisors for being in compliance with the target behaviors; posting graphic feedback charts of the ventilation violation notices in the mine office; delivering verbal feedback at biweekly safety meetings with the supervisors; and when a section was found to be noncompliant, the company safety inspector would stop coal production until the hazardous condition was corrected. Each section was observed once per week on a random basis.

Night Shift Work

Research by Andlauer (*2*) suggests that workers performing routine tasks during periods of low alertness and arousal will tend to introduce few errors into these tasks. However, the inhibited state of psychological arousal coupled with a narrow conscious focus on the routine task at hand may not allow the employee to respond properly to emergencies, thereby promoting the causation of relatively severe accidents.

Wagner (*31*) examined this issue by comparing the average severity of night shift accidents that involved the operation of heavy mining equipment versus accidents involving miners performing other types of activities–ones that presumably require less vigilance to perform the job safely. The data for this study consisted of accidents reported to MSHA from 10 surface iron ore operations over a 10-yr period. These mines all worked an identical shift rotation schedule for that full 10-yr period.

Accidents were broken down according to the shift (day, afternoon, night) and according to whether the accident occurred during equipment operation (selected accidents) or during the course of performing some other type of activity (nonselected accidents). The average number of days lost per accident was used as the measure of accident severity.

Wagner (*31*) found that the average length of time to recover from mobile equipment accidents was significantly greater for accidents experienced during the night shift than for accidents experienced during the day or afternoon shifts. Among nonselected accidents, night shift accidents are also more severe, but by a much smaller margin compared with the other two shifts. These data appear to confirm findings by Andlauer (*2*) and others regarding automatic behavior and employees' inability to respond adequately in emergency situations during times such as the night shift when vigilance is difficult to maintain.

EMPLOYEE CONTROL

Three variables have been studied that concern the extent to which employees have the opportunity to influence what happens to them on the job: (1) worker participation in problem solving, (2) worker autonomy, and (3) decentralized decision making. Although the meaning of worker participation in problem solving is rather self-evident, the latter two variables may not be as easily understood. Definitions of autonomy include: the amount of control employees have over what happens on the job; the extent to which employees see themselves as free to do what they want in accomplishing their work; perceived self-determination (*13*). One way of increasing perceived autonomy is by increasing employees' opportunity to influence decisions that affect them.

Although the notion of decentralization can be applied to hourly employees, it is more typically used to characterize decision making at higher levels in the organization. Webber (*32*) refers to decentralization as the extent to which higher executives delegate authority to make decisions to subordinate managers.

Worker Participation In Problem Solving

Bell (*3*) reports that injury rates at an underground silver mine were significantly lower following the institution of an organization development effort. A primary feature of this intervention was the formation of problem solving teams. A series of meetings took place in which high-priority issues facing the team were systematically examined and resolved. These meetings usually were conducted with the aid of a consultant who acted as a facilitator. Problems were defined and clarified, alternative solutions were evaluated, preferred solutions were implemented, and the effects of actions were monitored for desired results. Team-building meetings began at the top of the organization, involving the president and those reporting to the president. During the last phase of the project, team-building meetings were held with shift bosses and their workcrews.

Similarly, Edwards (*10*) reports that the introduction of quality circles at a large surface coal mining operation brought about a significant reduction in the accident rate.

DeMichiei's (*9*) questionnaire results (based on the responses of mine managers and safety officials) suggest that good ideas fostered by miners get more serious consideration from management at low-accident rate mines than at high-accident rate mines.

DeMichiei (*9*) makes the following three observations based on interviews with miners:

(1) At low-accident rate mines, miners indicated that individuals in key management positions were receptive and responsive to miner requests and frequently solicited input from the miners concerning mine policies and procedures.

(2) At several low-accident rate mines, miners indicated that management earnestly encouraged interaction between themselves and labor representatives. Management at most of the low-accident rate mines recognized the importance of labor safety and health committees and

actively sought out their participation in resolving safety and health problems.

(3) Miners at several high-accident rate mines believed management to be one-sided since they had little input into the decision making process.

Worker Autonomy

The results of the autonomous workgroups experiment at Rushton Mining Co., Osceola Mills, PA, suggests that increasing miners' autonomy may have been responsible for the improvements that were observed in mine safety. Although this intervention entailed making a number of changes to the organization, one of the most notable changes was the creation of self-managing coal mine face crews. These crews were given the entire responsibility for making all the decisions pertaining to the day-to-day production of coal from their sections. Crew supervisors were no longer involved in making production decisions. Their primary responsibility was to maintain the safety of the crew.

It is actually very difficult to determine what role autonomy played in producing the safety improvements. Goodman (*16*) notes that any of the following changes could have been responsible for the safety improvements:

(1) The experimental group received more formal training about safety practices and the law.

(2) The experiment introduced a new reward system to motivate the workers toward good safety practices. Intrinsic rewards were increased: The workgroup had been restructured to provide the workers greater opportunities for feelings of responsibility and accomplishment if safety levels improved. Extrinsic rewards were also increased through formal feedback sessions for the workers concerning their performance on such activities as safety.

(3) The supervisors in the experimental section were no longer caught in the conflict between production and safety. They could expend all their energies on safety. Supervisors in the nonexperimental sections had continually to balance production and safety demands.

Sanders' (*27*) findings, based on a cross-lagged panel design, suggests that a causal relationship exists between greater decentralization of decision making (down to the miners' level) and a lowering of the rate of lost-time injuries. He states, "mines in which miners are given decision responsibility and autonomy tend to have a lower incidence of injuries than other mines."

Decentralized Decision Making

DeMichiei's (*9*) questionnaire results (based on the responses of mine managers and safety officials) suggest that section supervisors at high-accident rate mines did not have as much freedom to make decisions concerning health, safety, and production as did section supervisors at low-accident rate mines.

Braithwaite's (*5*) case study of five coal companies with outstanding safety records suggests that decentralization of decisions regarding safety is a characteristic that is common among the large mining companies with better safety records.

These results concerning a positive association between decentralized decision making and mine safety do not contradict those discussed earlier concerning the value of upper management's interest and commitment to ensuring their miners' safety. As Gaertner (*14*) points out, upper management can express this commitment through setting safety-oriented policies and showing support for those charged with the responsibility for seeing to it that safety policies are being implemented and adhered to, as well as by frequently reviewing safety performance and generally keeping abreast of what is being done to maintain and improve safety. However, this does not mean that upper management should be running the show. Braithwaite notes that in mining companies with better safety records, upper management tends to delegate the responsibility for implementation and adherence to safety policies to line management. The fact that upper management delegates this function does not mean that they are not keeping a close watch on safety performance or that they are disinterested in employee safety.

MANAGEMENT-LABOR RELATIONS

This category includes the variables: overall labor relations climate, management concern for labor, and labor support for safety disciplinary actions. A considerable amount of evidence is accumulating to suggest that there is a significant positive association between the favorableness of the management-labor relationship and mine safety. Part of this association reflects the tendency for good labor relations to result in a safer environment and better employee compliance with safety rules. However, part of this association may reflect the tendency for changes in safety to produce changes in management-labor relations. For instance, a deterioration in safety could tend to cause a deterioration in management-labor relations. No doubt there is a reciprocal relationship between these two factors. Given the type of research evidence available, it is not possible to specify the predominant direction of causality. Nevertheless, the fact that a consistent positive association between these two factors has been identified is worth noting and has important implications for the achievement of a safer mining industry.

Overall Labor Relations Climate

Gaertner's (*14*) analysis of factors correlated to coal companies' safety performance indicates that the injury rate in companies with a negative labor relations climate is almost double that of the rate in companies with a positive climate. He also compared the two groups of companies in terms of the average annual rate of MSHA citations per mine for significant and substantial safety violations. Gaertner found that the rate for companies with positive labor relations was only about a third as high as the rate for companies in which the labor relations climate was relatively negative.

As part of the National Academy of Sciences (*21*) study, interviews were conducted with miners and mine managers at twelve large underground coal mines (150 workers or more). These mines were selected partially because they represented the extremes of safety performance, i.e., seven had quite low injury rates and five had quite high injury rates. The researchers note the following concerning the labor relations climate at these two groups of mines: "at all seven mines with low injury rates there appeared to be a cooperative attitude between management and labor; an adversarial attitude was observed in three of the five mines with high injury rates."

Both Gaertner (*14*) and the National Academy of Sciences (*21*) researchers point out that managers at mines with favorable labor relations usually had an open door policy, i.e., they were more accessible to hourly employees.

Management Concern for Labor

DeMichiei's (*9*) questionnaire results suggest that management at high-accident rate mines is less interested in the welfare of workers both on and off the job than management at low-accident rate mines. These results are based on the perceptions of salaried employees (includes mine superintendents, section supervisors, and mine safety department personnel).

Pfeifer's (*25*) questionnaire results suggest that supervisors in low-accident rate mines "more often show real concern for workers' welfare." These results are based on the perceptions of underground hourly employees.

Labor Support for Safety Discipline

DeMichiei's (*9*) questionnaire results suggest that section supervisors in low-accident rate mines received more support from safety committeepersons when reprimanding miners for unsafe acts. Based on interview data with miners he states,

> A significant finding at 11 high-accident rate mines was statements made by safety and health committees concerning their reluctance to support management's decision to reprimand miners for unsafe acts, even though such actions were justified. They stated that if such support was given to management, the rank and file miners usually reacted in a hostile manner. Management believed that such reaction by labor representatives prevented a good faith effort on the part of both parties to promote health and safety at the mines.

This same issue was examined in the part of the National Academy of Sciences (*21*) study that compared underground coal mines with either very low- or very high-accident rates. The researchers note that at all of the seven low-injury rate mines the union generally supported the company's enforcement of safety rules.

SUPERVISOR-EMPLOYEE INTERACTION

The miners' immediate supervisor has a great deal of impact on the extent to which safe working conditions exist and the extent to which miners comply with safety regulations. Variables dealing with the supervisor-employee relationship that have been addressed by mining industry safety researchers include: reporting hazards to supervisor, employee development, praise for working safely, and communications to miners. No doubt many of the variables listed in the other categories are also heavily influenced by the immediate supervisors' behavior, e.g., management-labor relations and role conflict.

Reporting Hazards to Supervisor

Pfeifer's (*25*) questionnaire results suggest that miners in low-accident rate mines reported small accidents and safety and health hazards to the supervisor more often than miners in high-accident rate mines. Similarly, DeMichiei's (*9*) questionnaire results suggest that miners contacted section supervisors regarding unsafe conditions more often at low-accident rate mines than at high-accident rate mines.

Employee Development

Sanders' (*27*) questionnaire results suggest that supervisors at mines with low-accident rates did more to instruct, guide, coach, and develop their employees' talents and abilities than supervisors at mines with high-accident rates.

Praise for Working Safely

Although the intervention involved several other changes, one of the primary things Uslan (*30*) taught the supervisors of salt mine employees to do was to systematically praise their employees for working safely. A significant reduction in the rate of eye, head, hand, and back injuries took place following the intervention.

Similarly, Pfeifer's (*25*) questionnaire results suggest that in comparison with high-accident rate mines, supervisors in low-accident rate mines were more likely to give miners a pat on the back when they followed safety procedures.

Communications to Miners

DeMichiei's (*9*) questionnaire results suggest that there is more conflict or misunderstanding over directions and job assignments given at high-accident rate mines.

INDIVIDUAL MINER

Each of the variables in this category characterize a single person or a single person's workrole. Variables in this category that have been addressed by safety researchers in the mining industry include: absenteeism, coworker relations, role ambiguity, role overload, role conflict, and age. No doubt the three variables concerning the individual's role are also heavily influenced by the immediate supervisor and by some of the variables listed under the organizational category, e.g., training, feedback, and management planning.

Absenteeism

Goodman (*18*) examined the effects or consequences of absenteeism on accidents. His central premise is that lack of familiarity leads to more dangerous conditions that, in the absence of compensatory changes in the level of care taken by a miner, would contribute to higher rates of accidents. Unfamiliarity can affect three types of people in coal mining: 1) miners who have just returned to the mine after being absent, 2) miners assigned as a replacement for a miner who is absent, and 3) adjacent miners. In a typical crew configuration, most mining activities require coordination among pairs of individuals who work closely together: the miner operator and the helper, the roof bolter and the helper, and the two shuttle car operators. Considering such dyads, the worker adjacent to the replacement may also be placed in a more dangerous situation because of lack of familiarity with the replacement's mining practices, and resulting difficulties in coordinating activities in an inherently dangerous environment. Hence, this adjacent worker or partner of a replacement is expected to have a higher probability of having an accident.

A data set was created that kept daily records on absences, replacement policies, and accidents. Information from five mines on these variables was obtained during approximately 70,000 miner days worked. This corresponds to roughly 60 production crews observed for an entire year. Using multiple regression analyses, accident rates were computed and comparisons made between each of the following 11 dyad-familiarity categories:

A Two regulars, neither absent previous day.

B Two regulars, one absent previous day.

C Two regulars, both absent previous day.

D Two replacements, neither absent previous day.

E Two replacements, one absent previous day.

F Two replacements, both absent previous day.

G One regular, one replacement, neither absent previous day.

H Regular absent previous day, replacement present previous day.

I Regular present previous day, replacement absent previous day.

J One regular, one replacement, both absent previous day.

K One miner working without partner.

Goodman (*18*) found that in comparison with category F, the accident rates for categories A, C, and D were each significantly lower. Most of the other expected differences between pairs of accident rates were in the expected direction, but were relatively small in magnitude. Goodman concludes that prior day absences have the effect of increasing accidents, and that regular miners have lower accident rates than replacement miners.

DeMichiei's (*9*) questionnaire results suggest that absenteeism is much more of a problem at high-accident rate mines than at low-accident rate mines.

Absenteeism was one of the issues examined in the part of the National Academy of Sciences (*21*) study that compared underground coal mines with either very low- or very high-accident rates. The researchers note that the five mines with high-injury rates tended to have considerably higher absenteeism rates.

The responses miners and supervisors gave in Pfeifer's (*25*) questionnaire study of the differences between high- and low-accident rate mines suggest that miners in low-accident mines had to take care of absentees' jobs significantly less often than miners in high-accident mines.

Coworker Relations

Pfeifer's (*25*) questionnaire results suggest that in comparison with the high-accident mines, miners in low-accident mines are more apt to believe that miners get along with each other and that they can depend on each other.

On the basis of interviews with miners, DeMichiei (*9*) reports that in comparison with low-accident mines, more miners at high-rate mines indicated that they were troubled by some of their coworkers' behavior. These complaints were centered around "freeloaders who often took advantage of disability compensation, individuals who failed to pull their share of the workload and persons who abused absentee policies for personal gain."[4]

[4]DeMichiei did not perform statistical tests on differences between the interview responses of various personnel from high- versus low-accident mines. Therefore, such differences are not included in table 2. DeMichiei did perform statistical tests on differences between the questionnaire responses of various personnel from high- versus low-accident mines, and those differences found significant ($p < .05$) are listed in table 2.

Role Ambiguity

Pfeifer's (*25*) questionnaire results suggest that in comparison with the low-accident mines, miners in high-accident mines spend more time working without clear-cut duties.

Althouse's (*1*) findings suggest just the opposite. He collected data concerning the extent to which coal miners experience 30 separate dimensions of job stress from the same sample of mines that Pfeifer (*25*) studied. Very little evidence of any differences in the self-reported levels of stress experienced by miners employed at high- versus low-accident rate mines was found. However, contrary to the hypothesis–that miners at high-accident rate mines would report higher levels of perceived role ambiguity than miners at low-accident rate mines–Althouse (*1*) found just the opposite. The *low* accident, rather than the high-accident sample reported significantly higher levels of role ambiguity. In other words, miners in low-accident mines were more likely to report that the clarity of responsibility and certainty of objectives on their jobs was ill-defined. Obviously, more research evidence is needed in order to form any conclusions about the relationship between miners' role ambiguity and safety.

Role Overload

Pfeifer's (*25*) questionnaire results suggest that in comparison with the high-accident mines, significantly fewer miners at low-accident mines report that they are expected to do too many things in too little time.

Role Conflict

Pfeifer's (*25*) questionnaire results suggest that in comparison with the high-accident mines, significantly fewer managers in low-accident mines felt that miners had to answer to more than one person.

One of the variables considered in Sanders' (*27*) cross-lag panel study of mine safety was miners' ratings of the consistency of the orders they were being given. Sanders (*27*) found that increases in the lost-time injury rate tended to bring about increases in the rated consistency of orders, which then appeared to decrease the lost-time injury rate ($p < .10$).

These findings concerning miners' perceptions of role ambiguity, overload, and conflict may all be indications of insufficient management planning at the high-accident rate mines.

Age

The National Academy of Sciences (*21*) study looked at the relationship between age and various accident rates for 15 of the largest underground coal producing companies in the United States. These companies provided data to the researchers concerning the age of their work force, and the accident data came from the reports these companies filed with MSHA concerning lost-time injuries that occurred in their mines during the 3-yr period 1978 through 1980. The researchers found that there is no evidence of an age trend with respect to fatality rates or permanent disability injury rates. However, there is a very marked correlation between age and lost-time injury rates. Miners between the ages of 18 and 24 have a lost-time injury rate nearly twice that of miners 25 to 34, who have a rate about 25 pct higher than miners 35 to 44, who in turn have a rate over 40 pct higher than miners who are at least 45 yr of age. Hence, a young miner (18-24) is about three times more likely to be injured than is a miner 45 yr of age or older, about twice as likely to be injured than is a miner 25-44. This relationship is consistent across the 15 companies that provided data on the age of their work force, as well as for each of the years 1978, 1979, and 1980. Furthermore, the strong association between age and lost-time injury rate was apparent for each of the major categories of accident types that cause injuries.

Findings of nonsignificant relationships to mine safety. Many examples of nonsignificant relationships between mine safety and various organizational and behavioral variables have been reported. Because these variables are so numerous, they will not all be listed. The interested reader should examine the results of the analyses of responses to questionnaire items reported in the large survey studies conducted by DeMichiei (*9*), Pfeifer (*25*), and Sanders (*27*).

Two variables have been examined in a relatively thorough manner and very little evidence was found to suggest that they are related to differences in mine safety performance: (1) Althouse (*1*) found that self-reported levels of job stress and psychological strain were NOT significantly different for miners at 14 high- versus 14 low-accident rate coal mines. (2) Goodman (*17*) found that the rate of accidents was NOT significantly affected by the introduction of a safety incentive program at four different coal mines. Likewise, Gaertner (*14*) found that there was essentially no difference between the injury rate for companies using versus not using a safety incentive program. It may be that safety incentive programs need to be designed differently than those examined by Goodman (*17*) and Gaertner (*14*) in order to have a significant impact on miners' injury rates. Goodman suggests several ways that the plan studied could have been made more effective. It may be well worth having a safety incentive program even if it does not by itself cause statistically significant reductions in the injury rate. Safety incentive programs represent one of several mechanisms that management could use to communicate their concern for employees' welfare and the fact that they want their employees to focus on working safely. For a discussion of mine operators' views on safety incentive programs see Miles (*19*).

OVERVIEW OF FINDINGS AND THEIR LIMITATIONS

Given the nature of the experimental designs and the data collection methods used to conduct most of the research presented in this review, there are some serious limitations to what can be safely concluded from any one study about how an organizational or behavioral factor influences mine safety. In most of these studies several alternative explanations exist for the observed correlations or for the observed changes in safety performance. Future studies of mine safety should seek to use longitudinal designs, control groups, and multivariate analyses. Two significant limitations to performing the types of research that would yield the most convincing results are (1) the length of time allowed for completing research projects is typically insufficient to permit analyses to be performed that are based on a longitudinal experimental design, and (2) it is difficult to find companies that are willing to participate in the research, especially if the research will require extensive data collection or entails significant changes to well-established practices.

Another limitation of the current set of research findings concerns the extent to which these findings can be generalized to all segments of the mining industry. The bulk of the research has been conducted at large underground coal mines and large coal mining companies. Therefore, it may be inappropriate to assume that these results would also be true of smaller mining operations, surface mining operations, or noncoal mining operations. The best management practices for achieving a good safety record at large mining operations may not be feasible or practical for relatively small mines. Conversely, the best management practices for achieving a good safety record at small mining operations may not be practical for relatively large operations. Future research should be performed to discover why the fatality rate is so much higher at small operations, and to discover what accounts for differences between small mine operations that have, versus those that have not been successful at maintaining a good safety record.

Certain variables are emerging as statistically significant correlates of mine safety in multiple studies involving different samples of miners and different research methods. For instance, it appears that better labor-management relations, greater employee involvement in decision making, and lower absenteeism all exert a positive influence on mine safety. Several aspects of first line supervisors' interactions with miners also appear to be important, as well as management's ability to communicate to the miner that they truly consider the employees' safety and welfare as a top priority. Undoubtedly, a clearer picture of the factors important for achieving good safety performance will emerge as more research evidence accumulates.

Another reason that these research findings are noteworthy is that most of the variables which appear to be playing a significant role in achieving a good mine safety record are within management's ability to control. The next section of this report lists some of the recommendations that the authors of these studies have made concerning strategies for improving mine safety. One should bear in mind that these recommendations are based on research findings that are subject to the above mentioned limitations.

RECOMMENDATIONS FOR IMPROVING MINE SAFETY

Many of the articles and reports cited in this review list specific recommendations for mine operators and other mining officials concerning the achievement of a good safety record. These recommendations mostly fall into one of the following nine categories: safety programs and their directors, labor-management interaction, industry commitment, top management commitment, training, employee motivation and/or incentives, supervisor–employee interactions, management planning, and absenteeism. The recommendations made concerning each of these topics are listed below. They vary widely in terms of the specificity of recommended action.

1. Safety programs and their directors

DeMichiei (*9*):

• Management must establish a formal safety and health program, effectively communicate that program to employees and seek labor's active participation in a joint implementation of the program.

• Management should commit the funds and peoplepower necessary to establish a safety department and give its personnel the authority to implement the safety and health program effectively.

Pfeifer (*25*):

• Safety directors' jobs should be redesigned to provide for more time in developing company safety programs.

• Safety directors should be given more authority in the area of safety.

2. Labor-management interaction

DeMichiei (*9*):

• Management and labor must establish open lines of communication so that problems affecting health and safety can be freely discussed and mutually resolved. Open lines of communication must exist between all levels of management and labor so that unsafe conditions or practices can be corrected and employees can feel free to discuss safety issues without fear of adverse action.

- Management and labor must both recognize that safety and health is a joint responsibility, which will only be achieved through cooperative efforts. Management and labor representatives must take the lead in cultivating a cooperative atmosphere at the mine via joint informational meetings, safety inspections of workplaces, and increased interaction with the general work force.

- Management should actively involve representatives of labor on issues concerning safety, health, and production.

- Labor representatives must support mine management when it is necessary to reprimand miners for unsafe acts.

- Labor representatives must instill a sense of responsibility and accountability in the work force for their actions and resultant impact those actions may have on fellow workers.

- Management should solicit the assistance of labor in identifying and correcting unsafe conditions and practices. Conversely, labor should accept the joint responsibility in this endeavor.

- Management should periodically review and solicit the opinions of miners concerning established mine policies and procedures to determine their effect on the miners' morale.

National Academy of Sciences (*21*):

- There is a need to establish joint labor-management safety committees at each mine.

Pfeifer (*25*):

- Miners need to be able to better communicate to management problems affecting their health and safety.

- Miners should be given a hand in the establishment of new company safety procedures, or, at a minimum, the reasons for new safety procedures should be better explained to miners.

3. Industry commitment

National Academy of Sciences (*21*):

- Encourage industry leaders to reinforce the value and importance of safety.

> ... saving lives and minimizing injuries are deeply held social values. However, it may be necessary 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.

- Encourage publication of annual rankings of companies by their injury rates.

- Publicize the evidence that productivity and safety can be positively related.

> The common denominator in achieving both a good safety record and high productivity 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 the researchers found associated with effective programs) is also likely to listen to employees' ideas for improving productivity.

4. Top management commitment

Pfeifer (*25*):

- Coal companies need to formalize safety as an organizational goal.

- Coal companies should communicate to workers both verbally and through the behavior of management the importance of safety as an organizational goal.

- Coal companies need to place more emphasis on keeping good safety records and upholding the company safety record.

5. Training

DeMichiei (*9*):

- When formulating new training programs or revising existing programs, greater input should be solicited from labor by mine management. A thorough review by mine management, labor, and MSHA of existing training programs will ensure that such plans are tailored to individual mine needs.

- First line supervisors should be provided instruction and sufficient time for administering task training to subordinates.

- The means to measure the effects of both classroom and on-the-job training should be incorporated into training programs.

National Academy of Sciences (*21*):

- A major upgrading of the educational and training requirements that new and experienced miners, and also supervisors, must meet is needed.

Pfeifer (*25*):

• In addition to better training for miners, better training is needed for mine management beginning at the level of supervisor. Supervisors must be made aware that they serve as models for the miners working under them, and, consequently, they must follow all safety procedures.

Sanders (*27*):

• Training mine management in basic supervisory employee relations and planning skills would significantly impact on the injury rates of the mines.

6. Employee motivation and/or incentives

Pfeifer (*25*):

• Miners' jobs need to be redesigned in order to provide for satisfaction of miners' intrinsic needs such as recognition, responsibility, and variety of job tasks, and, so that they do not have to do many things at the same time, they do not have to work without clear-cut duties, and they do not have to answer to more than one person.

• Programs providing positive reinforcement for a variety of identifiable safe job behaviors need to be established for both underground miners and supervisors. Techniques, which should be used in providing incentives for safe job behavior, include making safety an integral part of worker performance evaluation and publicizing outstanding safety performance.

• Care must be taken in employing competition among workcrews to be sure that safety is included in the criteria of good job performance.

Goodman (*17*):

Goodman presents a great deal of advice regarding the appropriate design of bonus plans for improving underground coal mine productivity and safety.

7. Supervisor-employee interactions

Uslan (*30*):

• Supervisors can affect employee motivation to perform their jobs safely by: (1) encouraging employees to buy into explicit safety performance goals that are consistent with organizational objectives, (2) arranging conditions so that employees can accomplish goals, (3) determining rewards that employees desire and making these rewards contingent on high levels of safety performance, and (4) ensuring that employees understand the relationship between safety performance and the receipt of rewards.

DeMichiei (*9*):

• Management should periodically monitor on-the-job work procedures to ensure that labor has the necessary experience or qualifications to recognize adverse conditions.

8. Management planning

DeMichiei (*9*):

• Management should formulate, implement, and enforce systematic mining cycles and standardized work procedures.

• Management should develop a comprehensive approach for mine development that includes activities such as materials handling, transportation and installation of equipment parts, etc. "Many times such activities are not considered as an integral part of the production."

• Management, labor, and MSHA must ensure that mine plans incorporate measures necessary to adequately control the physical environment. "Too often management continues to implement minimum plan requirements when, in fact, additional measures are necessary."

Pfeifer (*25*):

• Coal companies should establish better programs for maintenance of equipment.

9. Absenteeism

DeMichiei (*9*):

• Management should establish and implement an absentee policy that is firm, but fair, taking into consideration extenuating circumstances that could adversely affect mine personnel.

Goodman (*18*)–strategies for *coping* with miner absenteeism:

• Coal mine operators could better cope with absent members of underground coal mining crews by increasing familiarity among replacements for absent miners. This can be accomplished by organizing pools of replacement workers, and by giving special on-the-job training to a replacement and to the adjacent worker before work begins, in order to help familiarize each miner with the practices of its partner. Pools of replacement workers could be organized by job categories. For example, certain replacements would work as miner helpers, others as car operators. The pool could be further organized by mine sections; i.e., when possible, certain workers would always be assigned to certain work areas with which they are relatively familiar.

Goodman (*15*)–strategies for *reducing* miner absenteeism:

- Improve hiring practices through use of better selection procedures and realistic job previews.

- Institute employee assistance programs, health education programs, and selected types of in-house medical services.

- Maintain a record of each employees' daily attendance and post it somewhere for employees to see.

- Train supervisors in what they can do to prevent chronic absenteeism.

- Use positive reinforcement programs.

- Ensure consistency in the use of progressive disciplinary procedures.

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APPENDIX.-ANNOTATED BIBLIOGRAPHY

Althouse, R., and J. Hurrell. An Analysis of Job Stress in Coal Mining. NIOSH (DHEW) 77-217, 1977, 145 pp.; NTIS PB 274-796,

OBJECTIVE

This research examined how much job stress and psychological strain underground coal miners experience, and how levels of job stress and strain reported by miners who work in mines with high-accident rates compares with the stress and strain reported by miners who work at mines with low-accident rates.

METHODS

The data for this study were collected in conjunction with another NIOSH supported study by Pfeifer (*25*).[1] The data for the study were based on questionnaire responses from a sample of 486 miners and mine supervisors employed in nine different States. The sample included 14 matched pairs of coal mines, with one high-accident mine and one low-accident mine in each pair.

Analyses were conducted to address the hypothesis: mines exhibiting high rates of accidents adversely affect the experiences and attitudes of their employees compared with miners working in lower accident environments.

Measures of *job stress* pertain to characteristics of the miners' work environment, which pose a threat either as demands which they may not be able to meet or as insufficient supplies to meet their needs, such as, underutilization of abilities, participation, role conflict, inequity in pay, social support, and so forth.

A *strain* refers to any deviation from normal responses in a person. Among the indicators of psychological strain, three types of job satisfaction were measured (boredom, workload dissatisfaction, and general job dissatisfaction), and indices of somatic complaints and affective states (anxiety, depression, and irritation) were also included in the questionnaire.

RESULTS

Overall, there was surprisingly little difference between the high and/or low accident mines in terms of reported levels of stress and strain. With regard to job stress, the data indicate that there are few differences in job stresses between the high and/or low accident mine samples. Only one stress measure, Responsibility for Things, differed significantly between supervisors. As expected, the supervisors in high-accident mines were less satisfied than the supervisors in the low-accident mines with the amount of responsibility they have for seeing that the equipment being used is safe and well maintained, that various projects are carried out properly, and that budgets are well prepared and are adhered to.

Among the 30 separate job stresses associated with the reported experiences of *miners*, only three discriminated significantly between high and/or low accident underground miners; namely, fairness at work, role ambiguity, and responsibility for things. However, contrary to expectations, the data show that the *low* accident, rather than the high accident sample was significantly higher on those stresses. In other words, miners in low-accident mines were the ones who felt that the clarity of responsibility and certainty of objectives on their jobs were ill-defined, perceived less of a share in the opportunities to use their skills, abilities, and ideas, and experienced a significantly greater discrepancy between the actual amount of responsibility for setting projects and controlling the maintenance and safety of equipment than what they would have liked to have had.

With regard to psychological strains, the authors also found very little difference between the responses of miners working at high and/or low accident rates mines. The authors state that with one exception, the differences revealed were largely trivial ones. The authors suggest that the one reported difference (greater amount of personal energy off-the-job) probably reflects differences in the age of the miners in the two samples, and not the mine environments.

Althouse points out that this study is based on actual safety, not miners' perception of safety. This is an important point because the Pfeifer (*25*) results (based on the same sample of miners) indicate that not only did most of the miners from ALL the mines sampled actually perceive their mines to be safe ones, but that there was no significant difference in perception of safety between high and/or low accident mine environments among the underground miners, surface employees, or supervisors. One might expect that miners in high-accident mines would experience increased stress only if they *perceived* their mine as less safe, but this was not the case. Therefore, Althouse concludes:

> until more information is available, some healthy skepticism is warranted with respect to manifest, objective classification of mines by accident level and an easy inference that subjective job stresses are coincidental with that classification.

Althouse also points out that his findings do not necessarily mean that miners do not experience considerable psychological strain in *both* high-and low-accident mines. The researchers compared the reported stress and strain of coal miners with other nationally sampled blue-collar workers, and found that miners fared better than average on most measures of job stress, and, in fact, were low in subjective job stress experiences.

[1]Italic numbers in parentheses refer to items in the list of references preceding the appendix.

With respect to strain, however, miners were much more irritated than other blue-collar employees. They also experienced greater than average anxiety, depression, and had more physical complaints. However, on the average, they expressed higher job satisfaction, lower workload dissatisfaction, and less boredom than other blue-collar workers. Althouse concludes that miners were higher in their affective psychological strain, but lower than the average blue-collar worker on behavioral strain indicators.

Bell, C. The Hecla Story: Organization Development in the Hard-Rock Mining Industry. Paper in Human Engineering and Human Resources Management in Mining. Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, July 7-8, 1987; St. Louis, MO, July 15-16, 1987; and San Francisco, CA, July 21-22, 1987, comp. by staff. BuMines IC 9145, 1987, pp. 138-148.

OBJECTIVE

The purpose of this study was to determine the effects of a team-building and problem-solving organization development (OD) intervention on productivity and safety at an underground hard-rock mine.

METHODS

The OD program was instituted at the Hecla Mining Co.'s Lucky Friday Mine. This mine extracts an ore containing silver, lead, and zinc. It is located in the Coeur d'Alene Mining District of Idaho, and employs about 180 underground workers. Hecla also operates the Star Mine, which is located in the same area and employs about 270 miners. The two mines operate in the same geological formation, use essentially identical mining technology, and draw from the same labor pool. The Star Mines, which received no intervention during the time of the study, served as a comparison mine with the Lucky Friday Mine.

The primary intervention was through team-building and problem-solving meetings in which a boss and the immediate subordinates identified and resolved major problems to make their unit more effective. Some of the assumptions that underlie team building are as follows: (1) Workteams are the basic building blocks of an organization; (2) Effective team functioning requires good leader-member relations, clear team goals, clarification of role expectations, and individual and group problem-solving skills; (3) Teams can improve their performance by systematically solving the major problems that confront them; and (4) Enhancing workteam performance makes individuals more competent and organizations more successful.

The classic or team-building and problem-solving approach introduced at Hecla was governed by several principles:

1. Start team building and problem solving at the top of the organization and work through all levels,

2. Focus attention on intact workteams consisting of superiors and subordinates,

3. Focus on getting the job done; i.e., find better ways to accomplish the team's mission by solving major problems and seizing opportunities,

4. Be data based; i.e., discover problems, opportunities, and solutions through fact-finding and diagnostic procedures,

5. Be interaction oriented; i.e., develop and implement action plans to cause desired changes. Followup and evaluate actions to ensure a general team-building and problem-solving framework, but use additional OD techniques as they are appropriate.

The technique of team building involved a series of meetings in which high-priority issues facing the team were systematically examined and resolved. These meetings usually were conducted with the aid of a consultant who acted as a facilitator. Problems were defined and clarified, alternative solutions were evaluated, preferred solutions were implemented, and the effects of actions were monitored for desired results. Team building had two expected outcomes: the team's mission would be better accomplished, and work relationships among team members would be improved.

The effort began with five, day-long, team-building meetings with the president and staff. The outcome of these meetings was a formal statement of company philosophy and goals. An agreement on corporate strategy related to safety and productivity was developed. A statement of each department's goals, functions, responsibilities, and authority was also drawn up.

Next, team-building meetings were held with the top-management team at the Lucky Friday Mine, as well as with the operations team that included the shift bosses. After that, meetings were held involving the mine manager, mine superintendent, mine supervisors, shift bosses, and auxiliary support supervisors. These meetings dealt more intensively with issues of organizational coordination, communication, and cooperation. For example, support units were not delivering the needed services; some individuals and work units were not meeting others' expectations of what they should be accomplishing. The outcomes of these meetings were improved methods for getting the job done and detailed strategies for reducing mine accidents and injuries.

During the last phase of the project, team-building meetings were held with shift bosses and their workcrews. The meetings addressed four main questions:

1. What's preventing the crews from doing the job in the way they think it ought to be done?

2. What are the crews doing that helps them get the job done?

3. How can the crews get the job done more safely?

4. How can the crews make this a better place to work?

Other aspects of the intervention were as follows: a new performance appraisal system, a supervisory skills training program, and a review and critique of Hecla's safety program. The organization's safety functions were analyzed in various team-building meetings. These activities resulted in specific changes, including:

1. Reassignment of responsibility for the safety engineering, and safety inspection and enforcement.

2. Upgrade the mine safety-person position from supervisor to shift boss rank.

3. Commitment to give safety training to each new supervisor.

4. Commitment to develop a year-long schedule of safety incentive programs at the Lucky Friday Mine.

The effects of the intervention were assessed by comparing productivity and safety before and after the intervention at the Lucky Friday mine. Data were also collected on the productivity and safety performance of other nearby silver mines including one (the Star Mine) that was owned by the same company. These mines served as control sites.

RESULTS–SAFETY

During 1981, the first year following the intervention, Lucky Friday's injury rate fell to 12.9 injuries per 200,000 employee-hours: almost half of what it had been during the preceding 3 yr. This brought Lucky Friday's injury rate down to almost exactly the same level as the Star Mine and other nearby mines.

Since 1981, the injury rate increased somewhat in 1982, decreased again in 1983, and increased in 1984. But the injury rates remained well below rates experienced prior to the OD intervention. The average of the injury rates for the period from 1981 to 1984 is 38.2 pct below the average for the 3 yr prior to the intervention. The injury rate for the first 6 months of 1985 is extremely good. During this period, the employees at the Lucky Friday Mine went 88 working days without a lost-time injury: which is an all time record for this mine.

RESULTS–PRODUCTIVITY

The annual average tons of ore mined per production shift at the Lucky Friday Mine varied between 11 and 12 short tons per shift during the period from 1979 to 1982. Using the pre-intervention years of 1979 and 1980 as a basis of comparison, tons per employee-shift was 1.4 pct lower in 1981, and 4.5 pct lower in 1982. However, beginning in 1983, productivity began to improve. In comparison with the pre-intervention years, tons per employee-shift was 18 pct higher in 1983, 37 pct higher in 1984, and 54 pct higher during the first half of 1985. The impact of the OD program was not immediately reflected in improvements in stope miner productivity. Rather, there was a delay of over a year before increases began to materialize. One explanation for this may be that the company and the miners were engaged in a dispute over the administration of the contract system in late 1981 and 1982, with a slow down staged by the miners in 1982. The issues were resolved in late 1982 and productivity started on a steady rise.

CONCLUSIONS

To summarize, it appears that the OD team building intervention at Hecla was highly effective at improving both safety and productivity. The effects of the interventions were not a transient phenomenon. Data were collected for about 5 yr after the intervention was begun, and it appears that the initial improvements in safety and productivity have been maintained.

Bell estimates that to install an OD program in another mine similar to the Lucky Friday would require approximately 100 employee days of consulting plus expenses (i.e., from $80,000 to $150,000 over a 2 to 3 yr period), as well as the time periods which mine managers and miners would spend in team-building and problem-solving activities (approximately 25 h per person). For further details about this intervention, see Fiedler (*12*) and Buller (*6*).

Bennett, J., and D. Passmore. Probability of Death, Disability, and Restricted Work Activity in United States Underground Bituminous Coal Mines, 1975-1981. J. Saf. Res., v. 15, No. 2, 1984, pp. 69-76.

OBJECTIVE

The purpose of this study was to examine the correlates of injury severity in United States bituminous coal mines.

METHOD

Data were obtained from MSHA on all coal mining accidents and injuries during the period from 1975 to 1981. Data were eliminated from any mine other than an underground bituminous coal mine, from injured people under 18 and over 65 yr of age, from injuries at surface areas of underground mines, and from accidents that did not result in injuries. This left data on 82,945 injuries for analysis.

The criterion variable was binary. It was coded 1 if the injury resulted in death, permanent total or permanent partial disability, days away from work only, days away from work combined with days of restricted work activity, and days of restricted work activity only. It was coded 0 if the injury was so minor that it did not result in one of the above situations.

The variates studied were as follows: mining method, miner age, total mining experience, job experience, specific mine experience, job classification, time elapsed from start of work to accident, location of accident in mine, and year of accident occurrence.

The 14 variates that describe the mine and the injured miner were regressed on the categorical criterion variable using logistic regression techniques.

RESULTS–MINER CHARACTERISTICS

1. Age and experience. For practical purposes, none of the age and experience variates was related to the severity of injuries. Older miners with more experience in mining, at a particular task, and in a specific mine have the same chances for severe injuries as younger, less experienced miners. Bennett notes that previous studies of employee safety have reported both negative and positive correlations between age and injury incidence.

2. Job classification. Previous reports indicate that mobile equipment operators, supervisors, and maintenance workers ranked high in mine injury incidence. However, Bennett's findings for injury severity do not follow the same trend as those reporting injury incidence. Supervisors and maintenance workers were less likely to have serious injuries than all other job classifications (trackworker, beltworker, bratticeworker, and general laborer). Mobile equipment operators and all other job classification have the same probability of serious injury.

Bennett concludes that the potential for severe injuries has been underestimated for all other jobs that provide service and support activities (trackworker, beltworker, bratticeworker, and general laborer), and that training programs need to give greater attention to miners performing the service duties normally believed less dangerous.

RESULTS–OTHER VARIATES

1. Method of mining. Bennett found no statistically significant difference in the severity of injuries in conventional continuous, and longwall mining.

2. Location of accident. Both intersections and other locations in the mine had the same likelihood as the face for severe injuries. The area least likely to have had serious injuries is the shaft and slope. Bennett concludes that because safety training has focused traditionally on the face area, there has been an underestimation of the potential hazards in other locations of the mine.

3. Time elapsed since beginning of shift. No relationship was observed between the degree of injury and the shift time elapsed. Although the potential for fatigue increases as shift time passes, injury severity was distributed relatively evenly throughout each shift.

4. Year. The probability of injuries resulting in death, disability, or restricted work activity has been greater for each succeeding year from 1975 to 1981. Bennett concludes that current approaches to safety training have not reduced injury severity.

CONCLUSION

Bennett states the main implication of this study is that severe injuries can occur over a range of mine and miner characteristics: not merely with miners working at the face, as is commonly believed.

DeMichiei, J., J. Langton, K. Bullock, and T. Wiles. Factors Associated With Disabling Injuries in Underground Coal Mines. MSHA, June 1982, 72 pp.

OBJECTIVE

Information was gathered so that a comparative analysis could be made between two populations of underground coal mines: those that had experienced an exceptionally high nonfatal days lost (NFDL) accident rate (N = 21) and those that had experienced an exceptionally low NFDL accident rate (N = 19).

METHOD

Four criteria were used in the selection of mines. First, the mines employed at least 150 underground miners. Second, the mines had experienced either an exceptionally high or an exceptionally low NFDL accident rate over a period of 3 yr (1977 through 1979). Third, an effort was made to insure that the mines geographically represented the bituminous coal producing areas of the nation, and fourth, the sample represented both union and nonunion operations. Information pertaining to employment figures and accident rates was furnished by MSHA's Health and Safety Analysis Center. A sample of mines agreed to participate in the study that included 21 mines with an exceptionally high NFDL accident rate and 19 mines that had experienced an exceptionally low NFDL accident rate.

Three approaches were used to collect information: observing the mining methods and physical environment of the mine, interviewing miners, and administering questionnaires to individuals familiar with the mine's operation, i.e., mine superintendents, face supervisors, mine safety department personnel, mine safety and health committee members, and federal mine safety and health inspectors. The questionnaire included many rating scale items. The statistical significance of the difference between the mean responses of persons from high- versus low-accident rate mines was computed for each questionnaire item.

INTERVIEW RESULTS

1. Training

DeMichiei notes that in many cases classroom size was too large, ranging from 50 to 200 students. Miners indicated on-the-job training is the most effective training received, and section supervisors were often the individuals responsible for such training.

At low-accident rate mines, miners indicated that individuals in key management positions were receptive and responsive to miner requests and frequently solicited input from the miners concerning mine policies and procedures. The miners perceived management as being totally committed to ensuring safety and health. For example, section supervisors were given latitude and flexibility and encouraged to take additional precautions, when in their judgment, such a response was deemed necessary. Miners at low-accident rate mines often described management-labor relations as being one of cooperation. Management-labor relations were good not only between individual section crew members on the same shift, but also evident between these crews and section crews on other shifts.

At many high-accident rate mines, while relations appeared good between individual crew members and between other crews on the same shift, such a relationship did not extend to section crews on other shifts. Often they found conditions that should have been corrected by the preceding shift. Miners felt that upper management failed to recognize the effects this situation had, not only on the section supervisors, but also on the accident rate.

Unlike the low-accident rate mines, miners at several high-accident rate mines believed management to be one-sided since they had little input into the decision making process. At these same high rate mines, miners indicated that management lacked a systematic approach to decision making. Management's failure to plan resulted in conflicting job assignments, since neither the men nor the materials necessary to perform the job were available. The miners indicated situations such as these caused frustration, often leading to open hostility between management and labor.

In the majority of high-accident rate mines, the lack of communication was identified as a primary cause for poor management-labor relations. Miners in general and, more specifically, labor representatives indicated their opinions and suggestions were never seriously considered by upper management.

At several low-accident rate mines, miners indicated that management earnestly encouraged interaction between themselves and labor representatives. Management at most of the low-accident rate mines recognized the importance of labor safety and health committees and actively sought out their participation in resolving safety and health problems.

2. Morale

In seven high-accident rate mines, miners stated that poor morale was attributed to management's inability to plan effectively. Many times job assignments were conflicting, tools and materials necessary were not available, and management was not receptive to miners' concerns.

In the majority of high-accident rate mines, the miner's morale was negatively affected by management's failure to fairly and equitably enforce established company policies including absenteeism, job assignment, and standard operating procedures.

Miners at high-accident rate mines were troubled by some of their coworkers' behavior: freeloaders who often took advantage of disability compensation, individuals who failed to pull their share of the workload, and persons who abused absentee policies for personal gains. Management's reluctance to deal forcefully with these issues caused frustration, and a general disrespect towards mine management. While some of these problems did exist at low-accident rate mines, they existed to a much lesser extent.

Low-accident rate mines seemed to recognize that labor relations could be negatively influenced by inflexible company policies. When a company policy was causing conflict at the mine, management sought alternative solutions to the problem. For example, safety and health incentive programs were restructured to ensure more equitable accountability, vacations were scheduled to accommodate the miners, and absentee policies provided for being off work for extenuating circumstances. Moreover, policies were developed *in conjunction with labor* and, once established, were equitably enforced.

3. Safety

In five high-accident rate mines, the mine superintendents had no direct involvement in the mine's safety and health program. Responsibility for implementing the program was mainly the safety department's. Safety department personnel at these five high-accident rate mines identified the lack of upper management involvement in safety matters as a serious impediment to improving safety and health conditions at the mine. While safety personnel were given the responsibility, they lacked the authority to require operating personnel follow standard work procedures. Their role was one of mainly correcting unsafe conditions and the means to prevent them.

In seven high-accident rate mines, safety personnel stated it was virtually impossible to perform effectively due to the lack of safety personnel. Miners working on shifts other than the day shift stated safety department personnel very seldom, if ever, made underground visits during other shifts. Any involvement by the safety department personnel with miners was restricted to the shift the safety department worked. Miners further stated this lack of commitment was a disregard by management for their safety.

A significant finding at 11 high-accident rate mines was statements made by safety and health committees concerning their reluctance to support management's decision to reprimand miners for unsafe acts, even though such actions were justified. They stated if such support was given to management, the rank and file miners usually reacted in a hostile manner. Management believed that such reaction by labor representatives prevented a good faith effort on the part of both parties to promote health and safety at the mines. At these same mines there appeared to be a general mistrust regarding miners' motives related to health and safety issues, i.e., a suspicion that miners might be using safety as a means to gain contractual concessions.

> On the basis of the interview results DeMichiei concludes that: Many of the problems observed and discussed during interview sessions, with the exception of materials handling, do not account for a large number of disabling injuries. On the other hand, the existence of such conditions and practices may be indicative of the underlying causal factors that distinguish safe mines from unsafe mines.

QUESTIONNAIRE RESULTS

A questionnaire was administered to specific personnel groups other than miners (mine superintendents, section supervisors, mine safety department personnel, mine safety and health committee members, and federal mine inspectors) to gather information to supplement the data from observations and interviews conducted underground.

1. Training

Significant differences ($p < .05$) in mean responses to questionnaire items suggest that new miners in high-accident rate mines were less informed on how to do their jobs than new miners in low-accident rate mines, that supervisors at high-accident rate mines did not provide the same degree of instruction and guidance to miners as did supervisors in low-accident rate mines, and that the overall safety programs were not as effective.

2. Management quality

Questionnaire results suggest that section supervisors at high-accident rate mines did not have the same degree of freedom to make decisions concerning health, safety, and production as did section supervisors at low-accident rate mines. Management put off making important decisions and lost more worktime through poor scheduling and planning at high-accident rate mines more often than at low-accident rate mines. Furthermore, management at higher-accident rate mines provided less support for decisions made by section supervisors concerning safety than did management at low-accident rate mines.

3. Management-labor relations

Questionnaire results suggest that management at high-accident rate mines is less interested in the welfare of workers both on and off the job than management at low-accident rate mines. Additionally, there is more conflict or misunderstanding over directions and job assignments given at high-accident rate mines. Moreover, good ideas fostered by miners get more serious consideration from management at low-accident rate mines.

4. Physical environment

Questionnaire results suggest although adverse conditions were generally found in both high- and low-accident rate mines, management made more of an effort to control adverse conditions at low-accident rate mines than at high-accident rate mines. Furthermore, miners contacted section supervisors regarding unsafe condition more often at low-accident rate mines than at high-accident rate mines.

5. Safety

Questionnaire results suggest that miners in low-accident rate mines are better provided with supplies, equipment, and the tools necessary for job accomplishment than are miners at high-accident rate mines. Responses also indicated that miners at low-accident rate mines participate much more conscientiously in a personal protection plan for the feet, eyes, and head. It was also indicated that miners at low-accident rate mines would more readily contact their supervisor when unsafe conditions or acts were observed and that management more often provided safety manuals to the miners. Finally, section supervisors in low-accident rate mines received more support from safety committeepersons when reprimanding miners for unsafe acts.

6. Other findings

Union-Nonunion status. According to management and labor responses at the five (relatively large) nonunion mines that participated in the study, the reasons for the low accident and injury experience was the flexibility afforded management and labor in dealing with issues affecting safety and health, production, and other matters. For instance, all employees in these mines could be task trained in the operation of all mine equipment and subsequently operate this equipment when qualified. This permitted employees to freely exchange job assignments when mutually agreeable. It was claimed that these policies alleviated boredom, created more job satisfaction, and fostered cooperation and camaraderie between and among mine employees. Additionally, management at nonunion mines structured vacation periods, created innovative sick leave policies, and introduced profit sharing plans, all of which were tailored to meet the employees' personal and economic needs. This interest on the part of mine management in the well-being of the mine employees was thought to be responsible for high worker morale and positive attitudes toward safety and health.

Productivity and accident rates. Initial results for the 40 mines indicated that the low-accident rate mines produced significantly more short tons per worker day than the high-accident rate mines. After adjusting the data for the imbalance in geographic distribution and nonunion affiliation, the disparity still existed, but to a lesser extent.

Absenteeism. Survey results indicated that absenteeism was much more of a problem at high-accident rate mines than at low-accident rate mines. DeMichiei reports that the average rate of absenteeism at the 21 high-accident rate mines was approximately 16 pct. On the other hand, at the 19 low-accident rate mines, the average was approximately 8 pct.

Edwards, S. Quality Circles are safety circles. Natl. Saf. News, June 1983, pp. 31-35.

OBJECTIVE

The purpose of this study was to report the impact of quality circles (QC's) on safety at a large surface coal mine.

METHODS

The Captain Mine is located in southwestern Illinois. The mine had more than 500 United Mine Workers of America(UMWA) and company employees at the time of the intervention. One person was sent to a week-long QC facilitator training course. The facilitator, four department heads, and two union representatives from the mine committee were chosen to serve as a steering committee. This committee established general goals and ground rules for the QC's. They decided that items of a contractual nature would be off limits.

In the four departments selected for initial QC's, over 80 pct of the employees volunteered to participate. Members were randomly selected from this pool of volunteers. Each QC group consisted of approximately five to eight persons. In addition to the four quality circle groups, the mine safety comitteepersons also agreed to go through the circle training. All the circles focused on problems that genuinely affect production or job performance. The types of problems the circles identified are those that would be expected at most mines: tool shortages, lack of support equipment, unavailability of parts or supplies, poor communications, inadequate housekeeping, inefficiencies in work place layout, and so on.

QC meetings were usually held on shift for 1 h per week. Members first received training in circle techniques and processes. Training included such subjects as brainstorming, data collection and graph formats, and general group dynamics. During and immediately after their 8 h of training, the members used brainstorming to draw up a list of possible problems they would like to analyze and try to solve. Circle members voted and chose a problem they wanted to solve. They collected data on the problem. Once the problem was clearly delineated, they brainstormed possible solutions and projected how cost-effective solutions might be. When the analysis of a problem was completed, a proposed solution, or recommendation, was agreed upon. If the solution required higher level action, a management presentation was made.

RESULTS

A very important benefit of QC's at Captain Mine, not initially anticipated, was improvement in the accident rate of circle members. When comparing the number of accidents reported 6 months prior to the QC training with the number of accidents reported 6 months after the QC training, it was found that, for the overall mine, accidents decreased by 17 pct; for departments with circles, accidents decreased by 18 pct; and for the members of QC's, accidents decreased by 41 pct. Prior to their involvement in the circle program, circle members had 58 pct of the accidents on their shift. In the 6 months after circles began, members had only 31 pct of the accidents on their shift.

None of the circle projects involved what might be classified as strictly a safety problem. Yet, inherent in all the circles' projects, because they dealt with workplace layout or work procedures, was the potential for achieving a safer work environment.

The author concludes that "QCs quite possibly may provide a framework for employee input that helps improve safety and production, as workers not only identify a problem but become actively involved in the solution."

Fiedler, F. Structured Management Training in Underground Mining–Five Years Later. Paper in Human Engineering and Human Resources Management in Mining. Proceedings: Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, July 7-8, 1987; St. Louis, MO, July 15-16, 1987; and San Francisco, CA, July 21-22, 1987, comp. by staff. BuMines IC 9145, 1987, pp. 149-153.

OBJECTIVE

The purpose of this study was to determine the effects of a structured management training intervention on productivity and safety at an underground trona mine.

METHODS

Fiedler's structured management training intervention was instituted at Texasgulf's trona mining operation in Granger, WY. The intervention consisted of highly structured training in leadership and supervisory skills for managers and supervisors, using prepackaged and relatively standardized leadership and supervisory skills training programs, with relatively little interaction between the training consultant and company employees.

This underground mine is at the 1,300 ft level. Miners use continuous mining equipment and the room-and-pillar method of ore extraction. About 500 persons are employed at this mining operation, with half of the work force engaged in underground operations. Most of the surface work force is employed in the ore mill, which processes the trona, and in administrative positions. Training was conducted for managers and supervisors of the mine and ore mill. The Texasgulf Mine is located within a 10-mile radius of the other three major trona mines in the United States (Allied Chemical, Food Machinery Chemical (FMC), and Stauffer Chemical). These three mines provided an excellent basis for comparison since they share with Texasgulf the same geological conditions, the same labor pool, and compete in the same market.

The intervention began with a series of interviews to (a) familiarize the consultants with the organization, (b) identify the major goals of management and supervisors, and (c) develop a list of critical behaviors to construct a performance evaluation scale for assessing the effects of the intervention. The training program itself consisted of four basic elements, described below.

1. Objective supervisory performance appraisal. A performance appraisal system was designed so that managers and supervisors could become aware of their own strengths and weaknesses, and those of their subordinates. The rating scales concentrated on supervisory behaviors: how the supervisors act, and how they can change ineffective behaviors. This type of performance evaluation has been found effective by other industries in motivating employees to improve their behavior at work.

2. Leadership training. The intervention used a program developed by Fiedler called *Leader Match*. This program is based on a generally accepted view in the literature on leadership that the performance of leaders or managers depends both on their personalities and on the specific situations in which they operate. The method further assumes that it is generally much easier to change critical components of the leadership situation, than one's personality or deeply ingrained habits of interpersonal interactions with subordinates.

Leader Match teaches individuals to diagnose their own leadership styles, as well as to diagnose the leadership situations. The leaders are given detailed instruction on various methods for modifying the situations to match their particular management approaches and personalities. The instruction is provided by a trainer who uses a detailed manual, aided by videotaped illustrations, slides, and/or transparencies.

3. Supervisory skills training. This training method used videotaped vignettes in actual and staged settings that taught the supervisor how to deal with specific problems with employees. Some of the problems addressed included: reinforcing safe behavior, correcting an employee, overcoming resistance to change, handling an irate employee, and creating a cooperative workteam.

4. Institutionalization. Finally, to assure that the training would actually be used and would remain a permanent part of the organization, key personnel in the Texasgulf training department learned to administer the training methods.

Altogether, the Leader Match, supervisory skills, and employee motivation training are about 20 h in length.

The effects of the intervention were assessed by comparing productivity and safety before and after the intervention at the Texasgulf mine. Data were also collected from MSHA concerning the productivity and safety performance of three nearby trona mines. These mines served as control sites.

RESULTS–PRODUCTIVITY

The intervention began in February 1979. In terms of average short tons per employeehour during the years from 1978 to 1981, the productivity of the Texasgulf mine was higher than the industry average throughout all 4 yr. However, what is especially noteworthy is the DIFFERENCE between Texasgulf and the industry average is greater for each of the 3 yr following the intervention than it was during the year BEFORE the intervention. The difference is especially large during 1980, the first full year following the intervention. Texasgulf's productivity was 21 pct higher than the remainder of the trona industry during that year.

The annual average number of short tons of trona mined per machine shift at Texasgulf has increased steadily during 1982 to 1984. Unfortunately, comparable data for the remainder of the trona industry during this time period are unavailable. Although it is possible that the observed increases in productivity (relative to the industry average) could partially reflect changes other than the training intervention, Texasgulf managers recently reported they do not believe that any such changes have taken place at their company.

RESULTS–SAFETY

Prior to the training program, Texasgulf's safety record was considerably worse than other mines in the trona industry. In terms of number of injuries per 200,000 employeehours during the years from 1978 to 1981, the injury rate at Texasgulf was higher than the industry average throughout all 4 yr. However, it is also clear that 1981 represents a significant improvement over 1978 in both relative and absolute terms. The rate for Texasgulf in 1981 was almost half of what it was in 1978. Also, there are DIFFERENCES between the rates for Texasgulf and for the remainder of the industry. In 1978, the rate for Texasgulf was twice as high as the industry average. However, in 1981, the two rates are almost identical.

The rate has dropped dramatically from its high of almost 14 in 1978, as compared with the rates during the years 1983 and 1984, which were both below the level of four incidents per 200,000 employeehours. Again, recent interviews with Texasgulf managers suggest that they believe the reduction in accident rates is largely due to the structured management training program, and that other than the intervention, no changes have occurred which could account for the improved safety record.

CONCLUSIONS

To summarize, it appears that the structured management training intervention at Texasgulf was highly effective at improving both safety and productivity. The effects of the intervention were not a transient phenomenon. Data were collected for about 5 yr after the intervention was begun, and it appears that the initial improvements in safety and productivity have been maintained.

Fiedler estimates that to install the structured management training program of the type developed for the Texasgulf mine would cost from $4,000 to $10,000 for duplicating the already available training materials, and for consultant time required to train company personnel in administering the training program and to cover travel and other incidental expenses. This estimate does not take into account the cost of the time which the mine managers and supervisors would have to devote to the training sessions. For additional details also see Fiedler (*12*).

Gaertner, G. H., P. D. Newman, M. S. Perry, G. P. Fisher, and K. Whitehead. Determining the Effects of Management Practices on Coal Miners' Safety (contract JO145029, Westat, Inc.). BuMines OFR 39-88, 1987, 348 pp.; NTIS PB 88-221445.

OBJECTIVE

This study presented comparisons of the safety performance of underground coal mining companies using versus not using various types of management practices thought to affect safety.

METHOD

Data were collected from 10 underground coal mining companies that volunteered to participate in the research. There was considerable variation between these companies in injury rates, productivity, and size of mine work force. Some companies had excellent safety records and some had injury rates exceeding the national average.[2] Three of the ten companies were nonunion and the other seven were union. Data were collected from mines in eight different States (Virginia, West Virginia, Pennsylvania, Ohio, Illinois, Kentucky, Alabama, and Colorado).

Data were collected from company and mine records, and from interviews conducted with company- and mine-level personnel, including top level company officials, supervisors, and hourly employees. The interviews dealt with company safety policies, management's commitment to safety, and labor relations. Data were requested from MSHA on injuries, safety violations, production, and employment for the 62 mines being operated by the 10 companies in this study. MSHA provided data on these variables for the 5-yr period from 1980 to 1984.

The impact of selected safety policies was examined by looking at differences in safety indices between companies using a particular policy versus those NOT using that policy. Five policies were examined:

1. Whether the company had formal investigations of lost-time accidents more extensive than those required by law.

2. Whether the company had (and used) disciplinary policies applied to safety violations against miners and supervisors.

3. Whether the company had special programs for miners suffering repeated accidents.

4. Whether safety incentives (monetary or awards) were offered.

5. Whether combined safety-productivity incentives were offered.

Each company's use of safety policies was determined from the interviews conducted with both management and hourly employees. Since the injury rates being considered are for the period from 1980 to 1984, the researchers attempted to verify that the various policies under consideration (where they existed) had been established before 1980. At each company where one of the above mentioned policies existed, it was found that the policy had been put in place sometime prior to 1980.

RESULTS–SAFETY POLICIES

Table A-1 lists each of the five policies that were considered and shows the rate of injuries experienced by companies using versus not using each policy. It was found that in companies that DO conduct special accident investigations *beyond* legal requirements, the rate of injuries per 200,000 hr is 3.87 lower than the corresponding rate for companies that do NOT conduct such special investigations.

[2] In the 1983 the national average rate of injuries in underground coal mines was 10.07 per 200,000 h of exposure.

Table A-1.–Injury rates[1] for companies using versus not using each safety policy

Policy	Used		Not used	
	Rate	Sample	Rate	Sample
Special accident investigations	6.32	3	10.19	6
Safety discipline policies ...	8.20	5	9.88	5
Accident repeaters program .	10.15	5	7.93	5
Safety incentives	9.04	7	9.04	3
Combined safety-production incentives	5.64	3	10.50	7

[1]Injuries per 200,000 h of exposure.

Companies were compared on the basis of whether or not they had safety discipline policies. When present, such policies seem to have a positive effect on safety (the difference in incidence rates between companies with and without special discipline policies was 1.68 per 200,000 h annually.) Gaertner notes that the importance of the disciplinary policy seemed to be less punitive than indicative of top managerial commitment to safe operations.

A policy element that did *not* appear to reduce injuries was programs for accident repeaters. Companies that had special programs to deal with repeaters actually had somewhat higher injury rates than companies which did not (10.15 versus 7.93). It may be that companies with severe injury problems are driven to undertaking repeater programs. Managers at companies supporting such programs frequently cited the costs of compensation as reasons for the programs.

Safety incentives–by themselves–appear to make no difference in terms of injury rates. The rates for the two sets of companies were identical (9.04). However, there was quite a difference between companies that had combined safety-production incentives and those that did not. This is somewhat surprising given the relative lack of effect of safety incentives alone. Companies with combined safety and production incentives averaged only 5.64 reported injuries per 200,000 h annually. Companies WITHOUT combined production-safety incentives averaged an 86 pct higher rate annually (10.50).

Gaertner attempts to explain why there is such a difference between the safety incentives versus the combined safety-productivity incentives. Safety incentives not tied to production tended to be relatively inexpensive and symbolic (T-shirts, caps, decals), and generally did not indicate a serious commitment by management to safety in the eyes of the supervisors and hourly employees. Rather they were usually intended as "reminders to the men, to keep thinking about safety," as one manager put it. Combined production-safety incentives seem more effective, and generally more costly. In one company, the cost of the production-safety incentives was 25 cents per short ton; in another it was 81 cents per short ton.

Although the above data suggest that using incentive programs may be an effective way to improve safety performance, other data reported in this study suggest that such programs may not actually be reducing accidents to the extent one might think. There may be a tendency for incentive plans to inadvertently encourage miners to work injured to avoid reporting injury and losing their incentive pay.

RESULTS–TOP MANAGEMENT COMMITMENT

Gaertner notes that there were differences in the ways which top management expressed its commitment to employee safety. First, as previously discussed, there were differences in the use of safety policies. Second, there was a difference in the company's choice of vehicles for stressing safety. There was a tendency for companies with better safety records to rely heavily on one or two means of promoting safety. In one company the means was training and the use of computerized technology. In a second company, it was in applying engineering knowledge to production and safety problems. In a third company, it was a regular formal program of management audits of safety performance combined with regularized formal contacts. There did not appear to be one best vehicle for promoting safety, but all had several features in common:

- Employee participation. The work force was involved in implementing the vehicle and evaluating its feasibility.

- Pride in the vehicle. The vehicle for stressing safety was often perceived as being invented at and being unique to the company.

- Vehicle was promoted by well-situated company advocate (not necessarily the company president or safety director). The vehicle seemed to be an effective way of illustrating to the work force that management considered safety to be a high priority.

RESULTS–LABOR RELATIONS CLIMATE

Based on information from interviews with management and the hourly work force, companies were categorized as having either a relatively positive or negative labor relations climate. Next, the rates of injuries and citations at companies with a positive climate were compared with the corresponding rates at companies with a relatively negative climate.

Companies with a positive versus negative labor relations climate were compared on two measures of safety. It was found that the injury rate in companies with a negative labor relations climate is almost double that of the rate in companies with a positive climate (11.50 versus 6.70). Companies were also compared in terms of the average annual rate of MSHA citations for significant and substantial safety violations per mine. The rate of such violations for companies with a positive labor relations climate was only about a third of the rate for companies in which the labor relations climate was relatively negative (12.73 versus 3.94).

Gaertner notes that in most companies where the labor relations climate was positive, the following conditions were observed:

• an available and often used open-door policy to upper management (hourly interviewees said they spoke directly with the Chief Executive Officer (CEO) or superintendent and that they got a perceived positive response);

• a fair percentage of time spent underground by company management (hourly employees appreciated underground contact with upper level management, and informal conversation let others know that visits had been made);

• a feeling of pride on the part of employees and supervisors in working for the company;

• multiple communication vehicles were in existence in companies with a positive climate (newsletters; numerous communications on bulletin boards in the bath-house; letters sent to the employee's house; informal meetings with individuals and groups of miners).

Gaertner cautions that the statistics presented above should be viewed as only tentative and preliminary evidence concerning the true effects these variables have on mine safety. They are based on data from only a very small sample of companies, and they are based on a correlational (single point in time) versus a longitudinal (across time) analysis of the relationships.

Goodman, P. S. Determining the Effect of Incentive Programs on the Occurrence of Accidents, Injuries, and Productivity–Final Report (contract JO145012, Carnegie-Mellon Univ.). BuMines OFR 47-88, 1987, 143 pp.; NTIS PB 88-234257.

OBJECTIVE

The purpose of this study was to evaluate the effect of a safety incentive plan on the occurrence of injuries at four underground coal mines.

METHOD

Goodman collected data on the lost-time accident frequency rate for 4 yr (from 1980 to 1983) from four underground coal mines owned by the same company and represented by the UMWA. These mines all instituted a nonmonetary safety bonus plan at the end of 1981, and the program continued until the end of 1983.

The basic structure of the bonus program was as follows. All employees with 1 yr or more of service can participate. Each month all employees without a lost-time accident receive a safety star for their hard hat. Each quarter employees without a lost-time accident are eligible for a drawing to win a major appliance. Employees must work 90 pct of scheduled workdays. At the end of the calendar year, each employee who has not had a lost-time accident will receive a safety prize.

Mines 1 and 2 are somewhat similar and located in the same mining area of West Virginia. Mines 3 and 4 are together and located in southern Illinois. Mine 4 was shut down after 1982.

RESULTS

A review of the data in table A-2 shows remarkable variability in lost-time accident frequency rate in the baseline years, 1980 and 1981. 1980 is more comparable with the rates in 1982 and 1983.

Table A-2.–Lost-time accident frequency rates[1] before (1980-81) and after (1982-83) institution of nonmonetary safety incentive program

Year	Mine 1	Mine 2	Mine 3	Mine 4
1980	6.58	5.64	7.14	5.22
1981	21.75	19.41	24.50	52.30
1982	7.96	6.80	12.45	10.28
1983	5.68	5.18	5.87	(2)

[1]Lost-time accidents per 200,000 h of exposure.
[2]Shut down.

In 1981 the rates are particularly high. Since 1981 was a strike year these high rates may reflect distractions surrounding pre- and post-strike activities. In any case, if the 1981 period is considered special, there does not appear to be a connection between the nonmonetary incentive scheme and reduced accidents (1980 versus 1982-83).

To get a more complete picture of the effects of the plan, data on miners' perceptions of this bonus plan were collected from miners at one of the mines (mine 2). Workers were asked about their perceptions of the safety program. These data are very important because they give some picture of the effectiveness of this safety bonus program. Solely looking at final incident data can be misleading. Miners' responses to the following interview question shows that a majority, but not all of the miners knew there was a safety bonus plan:

"Is there a safety bonus at this mine?"

CATEGORY LABEL	(pct)
Yes	75.7
No	20.0
Don't know	4.3
	100.0

Miners' responses to the following two interview questions suggest that the plan had not affected their safety consciousness or safety related behavior very much:

"How has the safety bonus plan affected your safety consciousness?"

CATEGORY LABEL	(pct)
Increase	11.6
No effect	86.5
Decrease	1.9
	100.0

"Has the safety bonus plan had an effect on your safety related behavior?"

CATEGORY LABEL	(pct)
Increase	11.5
No effect	86.6
Decrease	1.9
	100.0

Miners' responses to the following interview question suggest that the safety bonus had very little or no effect on improving how the crew works on safety issues:

"What effect has the safety bonus plan had on your making certain that everyone on this crew works safely?"

CATEGORY LABEL	(pct)
Increase	7.7
No effect	90.4
Decrease	1.9
	100.0

CONCLUSIONS

Goodman concludes, "The basic picture is that the safety program has had little effect on workers perceptions or motivation. Unless the program can change worker beliefs and behavior, it is not likely to lead to major changes in accidents." Goodman believes that such programs are not very effective because they do not identify critical safety behaviors and there is not a close connection between behavior and rewards. "The quarterly reward was on a lottery, and only one employee wins. The annual reward was over such long periods as to attenuate the relationships between behavior and rewards."

Goodman, P. Assessing Organizational Change: The Rushton Quality of Work Experiment. Wiley, 1979, 391 pp.

OBJECTIVE

The purpose of this study was to determine the impact of an intervention on safety, productivity, quality of employee work-life, and several other outcome measures. The major points of the intervention were as follows:

1. An experimental section called the "South" section was established in the mine, comprising 27 volunteers, 9 to a shift.

2. Every worker in the experimental section was on top pay. This meant the experimental section would cost at most $324 more each week than other sections, not a prohibitive cost factor to the mine's management.

3. All members of each crew were trained by the company to be capable of performing any job in the section, from continuous miner operation to roof bolting. The entire crew was also given special training in State and Federal mine safety laws, so each miner would know what constitutes a violation.

4. Each of the three crew supervisors in the section had responsibility and authority primarily for the safety of the crew. The responsibility to management for the day-to-day production of coal by the crew was transferred to the entire team of nine workers.

5. Grievances by any member of the section would be dealt with primarily by the crew involved, in what is sometimes called peer discipline. If the crew couldn't cope with a grievance itself, it would then be processed through the local union's formal grievance machinery.

METHOD

Rushton is a medium-sized mine in central Pennsylvania. There were approximately 180 employees when the experiment began late in 1973. Of these, 35 were managerial, the remainder were nonexempt and members of the UMWA. At the beginning of the evaluation, there were three working sections in the mine, a maintenance group, a general labor group, and the cleaning plant.

The changes which were hoped to facilitate improvements in safety were as follows: (1) the experimental group received more formal training about safety practices and the law; (2) the experiment introduced a new reward system to motivate the workers toward good safety practices. Intrinsic rewards were increased: the workgroup had been restructured to provide the workers greater opportunities for feelings of responsibility and accomplishment if safety levels improved. Extrinsic rewards were also increased through formal feedback sessions for the workers concerning their performance on safety and other activities. (3) The supervisors in the experimental section were no longer caught in the conflict between production and safety. They could expend all their energies on safety. Supervisors in the nonexperimental sections had continually to balance production and safety demands.

Safety was measured by the number and type of accidents, the number and type of violations, ratings on the quality of safety made by independent observers, as well as by the union and management, and by qualitative reports from the on-site observers. The experimental sections were compared with control group sections on these measures both before and after the intervention.

RESULTS

The accident data provide no conclusive evidence on whether the intervention had an effect. However, the accident data are not a particularly good measure of the intervention's effectiveness because the experimental section exhibited a very low accident rate before the intervention even began. (For accident rate data see Goodman (1979), table 12.1, p. 214.)

Analyses of the responses to interview questions suggest that most respondents viewed the program as positively affecting safety. If one divides union respondents into experimental and control, *both* groups endorse the positive effects of the intervention on safety over time. Members of management, many of who were not strongly committed to the program, also reported that safety practices had improved.

Analyses based on federal safety violations indicate that in the first experimental period (the first year following the intervention), there was a slight drop in violations in the South section (-7 pct) and a significant increase in the other two sections (+121 pct and +250 pct). (See Goodman, table 12.4, p. 220.)

Analyses based on the number of shifts lost by each section due to inspectors closing down a section indicate that at the baseline the sections are the same. In the first experimental period all sections show an increase, but the experimental section shows the smallest increase. In the remaining periods (December 1974 to December 1976), the number of shifts lost decreases virtually to zero. (See Goodman, table 12.5, p. 221.)

In the first experimental period the number of state violations in the South section is less than in the other sections and less than its own baseline. No differences were observed among sections in the remaining periods. Goodman concludes, "Overall there is a slight improvement in the experimental section (relative to the others) with respect to violations in the first 11 months of operation." (See Goodman, table 12.6, p. 222.)

Analyses based on quarterly global ratings of section safety by federal and state inspectors indicate that the experimental section's overall safety record was better than the other two sections, although the East section was virtually identical to the South section in the last half of 1976. (See Goodman, table 12.7, p. 223.)

CONCLUSIONS

Regarding the effects of the intervention on safety, Goodman writes:

> The overall finding is that the experimental intervention did lead to an improvement in safety practices... the experiment did affect safety behaviors, that is, the men in the South section put into effect safety practices that would prevent accidents. They were more pro-active toward safety than they had been prior to the experiment.

The structure of the program provided knowledge about safety practices that previously was not available. Making the supervisor's role safety, rather than production, "minimized the negative reinforcement workers sometimes received from their bosses when they wanted to do safety work." Periodic meetings with the miners provided them with formal feedback on how safety behavior matched safety goals; they were a problem-solving arena where new safety practices were developed, and offered a direct opportunity to reinforce good safety behavior. This is absent in most traditional safety programs. Lastly, the autonomous workgroup concept increased workers' feelings of responsibility for achieving high safety levels.

The mine president and many miners wanted the intervention to be expanded to the other three sections of the mine, and in August 1975 this proposal was put to a union vote. The proposal was rejected by a very narrow margin (79 versus 75). Many reasons have been proposed for the rejection, including the possibility that miners who were not in the experimental South section had become envious of the freedom, flexibility, and higher pay of the experimental section. By the end of 1977 the intervention efforts had entirely disappeared.

For further details see Trist (*29*) and Mills (*20*).

Goodman, P. S. Analysis of Miners' Job Attendance Behavior and Its Relationship to Miners' Accidents and Injuries–Final Report (contract JO328033, Carnegie-Mellon Univ.). BuMines OFR 60-86, 1985, 278 pp.; NTIS PB 86-216306.

OBJECTIVE

This study examined the effects or consequences of absenteeism on mining accidents.

METHOD

The concept of familiarity was introduced to explain the impact of absenteeism on accidents. Familiarity refers to the level of specific knowledge one has about the unique aspects of the workplace. This includes knowledge about the unique characteristics of particular machinery, materials, physical environment, people, and programs that exist in a particular mine section at a particular time. The central premise is that lack of familiarity leads to more dangerous conditions that, in the absence of compensatory changes in the level of care taken by a miner, would contribute to higher rates of accidents.

Unfamiliarity can affect three types of people in coal mining.

1. Because the physical characteristics of a mine section change from day to day, an absent worker, on returning to the mine will be less familiar with the workplace, and, ceteris paribus, will have a higher probability of having an accident.

2. When a miner is absent another miner is generally assigned as a replacement. Such a person is generally less familiar with the work setting and, ceteris paribus, more likely to have an accident.

3. In a typical crew configuration, most mining activities require coordination among pairs of individuals who work closely together: the miner operator and the helper, the roof bolter and the helper, and the two shuttle car operators. Considering such dyads, the worker adjacent to the replacement may also be placed in a more dangerous situation because of lack of familiarity with the replacement's mining practices, and resulting difficulties in coordinating activities in an inherently dangerous environment. Hence, this adjacent worker or partner of a replacement is expected to have a high probability of having an accident.

Data were gathered from production crews in five underground coal mines. A unique data set was created that traced on a daily basis the absence event, the company's policy on replacement, and the occurrence of an accident. Information on these variables was obtained during approximately 70,000 miner days worked, corresponding to roughly 60 production crews observed for an entire year. During these 70,000 miner days, the number of reported accidents was approximately 340, or about one accident every 205 miner days worked.

The following strategy was applied to each of the five mines:

(a) Define various mutually exclusive categories among which the degree of familiarity is expected to differ importantly.

(b) Assign every miner day to one of these categories and count the number of miner days worked in each of these situations (i.e., measure the level of exposure to danger).

(c) Count the number of accidents experienced by miners assigned to each of these categories.

(d) Compute accident rates (i.e., numbers of accidents per 200 miner days of exposure).

(e) Assess quantitatively the differences in accident rates across the familiarity categories.

Eleven dyad-familiarity categories were defined as follows:

A Two regulars, neither absent previous day.

B Two regulars, one absent previous day.

C Two regulars, both absent previous day.

D Two replacements, neither absent previous day.

E Two replacements, one absent previous day.

F Two replacements, both absent previous day.

G One regular, one replacement, neither absent previous day.

H Regular absent previous day, replacement present previous day.

I Regular present previous day, replacement absent previous day.

J One regular, one replacement, both absent previous day.

K One miner working without partner.

Multiple regression analysis was used to examine the effects of familiarity on accident rates. An observation is a dyad-familiarity category for a particular mine, and thus the sample size (with five mines and 11 dyad-familiarity categories) is 55. Accident rates are the dependent variable. Inter-mine differences were statistically controlled for, and a weighing procedure was used to adjust for large differences in miner days of exposure used in calculating the accident rates.

RESULTS

Working alone is the safest of the 11 categories of familiarity.

Categories A versus F. The hypothesis that two regulars, neither absent on the previous day have lower accident rates than two replacements who were both absent on the previous day received considerable quantitative support. The accident rates in the extreme high-familiarity category are estimated to be, on average, less than those for the extreme low-familiarity category by about 0.7 accidents per 200 miner days worked, with inter-mine differences and the varying levels of exposure taken into account. When compared with the average accident rate for the entire sample of 0.98 accidents per 200 miner days worked, this estimate of 0.7 suggests an impact of considerable importance.

Categories D versus F. The hypothesis that two replacements, neither absent previous day, have lower rates than two replacements both absent previous day received substantial quantitative support–the estimated difference is about .75 accidents per 200 days.

Categories C versus F. The hypothesis that two regulars who were both absent on the previous day have lower rates than two replacements who were both absent on the previous day received quite strong support, with an estimated differential of about .6 accidents per 200 days.

Most of the other expected differences between pairs of accident rates were in the expected direction, but were relatively small in magnitude.

CONCLUSIONS

The findings suggest that prior day absences have the effect of increasing accidents, and that regular miners have lower accident rates than replacement miners. Goodman states that although it seems clear that absences are not among the primary factors related to mining accidents, they may be important among those factors *that can be addressed by mine policy*. Thus, absenteeism appears to be one factor to be considered in programs designed to reduce accidents.

National Academy of Sciences–National Research Council. Toward Safer Underground Coal Mines. NAS, 1982, 190 pp.

OBJECTIVES

The purpose of this study was as follows:

1. Look for correlations between various factors and variations in the rate of lost-time accidents experienced in United States underground coal mines.

2. Look for factors that might account for variations in the rate of lost-time accidents experienced at the 19 underground coal mining companies producing the most coal in the United States.

3. Look for differences between mines that have an extremely high rate of lost-time accidents versus mines that have an extremely low rate of lost-time accidents.

Different sets of data were analyzed in order to achieve these three objectives.

METHOD–FIRST DATA SET

These data are based on the information mine operators provide to MSHA concerning accidents, employment, and productivity. Data on every lost-time injury that were reported to have occurred in a United States underground coal mine during the 3-yr period 1978 through 1980 were included in the analyses; 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. Fifteen large coal mining companies provided the researchers with data on the age of the underground miners in their entire work force.

RESULTS–FIRST DATA SET

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. Small mines (< 50) accounted for 15 pct of total employeehours, but 40 pct of all fatalities.

PRODUCTIVITY - SAFETY.–The researchers conclude 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.

AGE OF MINER.–There is no evidence of an age trend with respect to fatality rates or permanent disability injury rates. However, there is a very marked correlation between age and disabling injury rates. 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 pct higher than miners 35 to 44, who in turn have a rate over 40 pct higher than miners who are at least 45 yr of age. Hence, a young miner (18-24) is about three times more likely to be injured than is a miner 45 yr of age or older, about twice as likely to be injured than is a miner 25-44. This relationship is consistent across the 15 companies that provided data on the age of their work force, as well as for each of the years 1978, 1979, and 1980. Furthermore, the strong association between age and disabling injury rate was apparent for each of the major categories of accident types that cause injuries.

METHOD–SECOND DATA SET

The second data set consisted of a subset of the first data set. Analyses were performed on the data for 19 of the 20 largest bituminous coal producing companies in the United States in 1978. (One company went out of business shortly after 1978.)

RESULTS–SECOND DATA SET

The researchers found 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 were included in the analyses. The researchers conclude that "these differences are due, apparently, to factors *internal to the companies*." This issue was examined in greater detail in the third data set.

METHOD–THIRD DATA SET

Twelve large mines (150 workers or more) were visited by the research team. These mines were selected partially because they represented the extremes of safety performance, i.e., some had quite low injury rates and others had quite high injury rates. The research team 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. Three major types of characteristics thought to be associated with mine safety were investigated: (1) the quality of labor relations, (2) the extent of management's commitment to safety (as reflected by a proper balance between production and safety, safety meetings and contacts, rewards for safety, and good housekeeping in the mine), and (3) absenteeism rate.

RESULTS–THIRD DATA SET

The researchers state:

> All seven mines with low injury rates appeared to have a cooperative attitude between management and labor; an adversarial attitude was observed in three of the five mines with high injury rates. It is also apparent that the mines with higher injury rates tended to have higher absenteeism rates. In three of the five mines with high injury rates, at least one of the above mentioned aspects of management commitment to safety was found to be lacking.

The researchers conclude that differences in the injury rates of these 12 mines appear to be due in part to the degree of a company's cooperation with employees in its mines.

> At the seven mines with low injury rates that were visited, 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 re safety. At these mines the union generally supported the company's enforcement of safety rules.

CONCLUSIONS

Based on their visits to underground coal mines, their case studies of coal companies, and their discussions with industry, union, and government officials, the researchers conclude that among the most important factors influencing mine safety are as follows: (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.

Peters, R., and L. Schaffer. Field Tests of a Model Health and Safety Program for the Mining Industry. BuMines IC 9075, 1986, 36 pp.

OBJECTIVES

The objectives of this research were to better define the essential features of effective health and safety programs for the mining industry, to develop a health and safety program that incorporates these essential features, and to evaluate the effectiveness of the model program at a coal mining and a gold mining company.

METHOD

Based on a review of the safety literature, and what is known about the mining industry, a model program was defined in terms of five fundamental conditions:

1. There must be no separation of production and safety and health in the management of the mining operations.

2. There must be an honest commitment by the top managers to constantly improve the operation's health and safety performance.

3. Managers and supervisors at all levels must receive basic training in safety, health, and loss control management.

4. Management emphasis on health and safety in staffing and performance evaluation.

5. Feedback mechanisms that have reliable and readily detectable safety and health components should be used, e.g., investigation of all accidents and near misses, safety audits, and job performance sampling.

A written model program tailored to the two companies' circumstances and needs was developed and the following agreement was reached between the researchers and the top company manager at each company:

1. The top company manager accepted the program as conceptually sound and agreed to put it into effect in the company.

2. The researchers agreed to complete an initial health and safety audit of the company's operations and, from the information obtained, to define a program tailored to the company's circumstances and needs. The researchers and top company managers agreed that the model program would contain specific recommendations for management action.

3. The top company manager agreed to consider each recommendation carefully and advise the researchers of the decision regarding acceptance. If the decision was to not accept a recommendation, the researchers would be informed of the reason so they could record the information for use in the final evaluation of the program.

4. The researchers agreed to assist the manager in implementing the program by: (a) conducting 8 h of training for subordinate managers, supervisors, and shift bosses in loss control fundamentals; (b) providing 8 h of training to supervisors and workers selected by the top manager in the use of an accident investigation methodology developed

by the Bureau; (c) furnishing available materials for training mobile equipment operators and assisting in course development to improve the company's task training; (d) providing health and safety technical literature and other information related to the company's loss control problems; (e) visiting the company's operations once a month for a calendar year, or longer, to assist in program implementation and obtain evaluation data (and the manager agreed to permit the researchers unrestricted access to all elements of the operation for observation and to all available information related to occupational injuries, illnesses, accidents, near misses, and incidents of any kind that produce loss); (f) providing the company management periodically with an oral report on observations made, additional management actions recommended, and countermeasure options suggested for consideration; (g) at the end of the evaluation period, presenting an oral report covering all of the model program research at the company's operations.

In short, the model program was implemented primarily by providing training on loss control and accident investigation, and by providing technical assistance with health and safety problems.

The coal mining company was located in easter Kentucky. It operated two underground low coal drift mines using continuous miners and two surface mines using mountain top removal techniques. In 1982, the company's total salable production of coal was nearly 800,000 mt, of which 65 pct was from surface operations. Average employment during 1982 was 340. All of the hourly employees were represented by a union local.

The gold mining company was located in central Nevada. Ore was mined by power shovels and trucked to a crusher at the mine site. In 1982, this single mine moved approximately 2.203 million mt of overburden and other waste and 0.743 million mt of ore. There was no union. The average number of employees in 1982 was 113.

In order to assess the effectiveness of the program, monthly statistics were generated on the rate of occupational injuries and accidents, and the severity of injuries (as measured by the number of days of work lost during recovery), and employees were observed performing a large number of randomly selected jobs on several occasions throughout a 15-month period. The purpose of these observations was to estimate the proportion of the work force that was working in the presence of one or more of three types of safety deficiencies:

Type A–individual job performance deficiencies, which could be corrected by the employee along, e.g., an employee is observed not to be wearing a seatbelt.

Type B–individual job performance deficiencies, which could be corrected only through employer action beyond the control of the individual employee, e.g., an employee is observed driving a truck that does not contain a usable seatbelt.

Type C–deficiencies that were common to several jobs of the same kind, or various kinds, and correctable only through substantial changes by the employer in mining plan, operating policies, or job structuring, e.g., allowing deviations from the approved roof control plan.

RESULTS

During the 15 months of observation at the coal mining operation, the following improvements were noted: a gradual decrease in the rate of injuries per month, a substantial decrease in the severity of injuries (from 105 days lost per month to 10 days), and a substantial reduction in the proportion of sampled jobs with one or more safety deficiencies (from 74.3 pct to 36.6 pct). Although the proportions of all three types of safety deficiencies were reduced, the greatest reduction was in type A, e.g., failure to use personal protective equipment and messy work areas.

During the period in which the gold mining operation was observed, three types of improvements were noted. First, although there was no downward trend of significance in the rate of injuries per month, the severity of injuries decreased substantially–only one-third of the total days lost due to accidents in 1982 are attributable to accidents which occurred in the last half of that year. Second, the proportion of jobs with one or more safety deficiencies decreased substantially (86.4 to 19.1 pct). As at the coal company, the proportions of jobs having each of the three types of safety deficiencies were reduced. Substantial improvements in type C deficiencies occurred at the maintenance yard, crushing facility, mill and maintenance shop, and on the haul roads. Third, the incidence of accidents resulting in equipment and/or facility damage (but no injuries) was reduced by about 50 pct. This reduction in accidents is quite noteworthy, considering that the uninsured loss (cost of parts and labor for repairs) associated with the 56 noninjury accidents reported at this mine during 1982 was $235,950.

CONCLUSIONS

The researchers believe that it would take a minimum of 9 to 12 months to achieve full implementation of the model program in most mines, and that the model program can be implemented with minimal outside help. They suggest that because implementation is inexpensive and the loss reduction is very substantial, the benefit-to-cost ratio is quite favorable.

For additional details also see Schaffer (*28*).

Pfeifer, C., J. Stefanski, and C. Grether. Psychological, Behavioral, and Organizational Factors Affecting Coal Miner Safety and Health (DHEW contract HSM 99-72-151). 1976, 319 pp.; NTIS PB 275 599.

OBJECTIVE

Information was gathered so that a comparative analysis could be made between two populations of underground coal mines: those that had experienced an exceptionally high-accident rate and those that had experienced an exceptionally low-accident rate.

METHODS

Questionnaire data were collected from 14 matched pairs of coal mines, with one high-accident mine and one low-accident mine in each pair. Data were collected from 54 union officials, 102 supervisors, 27 safety directors, 32 mine managers, 77 miners' wives, 157 above-ground miners, and 612 underground miners. The topics covered in the survey were as follows: attitudes toward safety and accident causes, major problems in the mine, general company attitudes, general miner attitudes, physical and psychological problems, safety and health equipment, use of health programs, training, job behaviors, job satisfaction, company safety programs, and perceptions of outside organizations. The questionnaire included many rating scale items. The statistical significance of the difference between the mean responses of persons from high-versus low-accident rate mines was computed for each questionnaire item.

RESULTS

1. Attitudes toward safety and accident causes

The data indicate that differences in concern for safety practices from mine to mine are perceived by the personnel working at the mines, and that, in general, companies which are viewed to have a greater concern for safety practices do in fact have better safety records.

In comparison with the rating scale responses from miners in high-accident mines, miners in low-accident mines felt that keeping good safety records and upholding the company safety record were significantly more important to their companies, and that having competition among workcrews was significantly less important to their companies.

Mine personnel were asked the extent to which 18 different items were related to accidents in the mine. Four items were seen as related to accidents to a significantly greater degree in high-accident mines: dust, lighting, supervisors, and faulty equipment.

2. Major problems in the mine

All six groups of mine personnel felt that too much absenteeism was a problem in their mine. Labor groups felt that lack of management training and poor equipment maintenance were very often problems in their mine. Management groups, on the other hand, felt that too low worker productivity and too high job turnover were problems more often than not. There were no statistically significant differences between the responses of mine personnel from high-versus low-accident mines.

3. General company attitudes

Although managerial groups feel that more emphasis is placed on safety by the company than on production, this emphasis is not communicated to miners, who feel that the company places more emphasis on production. Pfeifer believes these results suggest that coal companies could communicate company policy and philosophy to miners in more effective ways than they have in the past. No significant differences were observed between the responses of high and low accident mine personnel to the questions in this section.

4. General miner attitudes

Underground miners appear to be much less fatalistic than has been assumed in the past. Responses to several independent questions confirm that miners do feel that they have some control over their safety.

Supervisors and management were asked the extent to which each of 12 miner attitudes contributed to accidents in their mines. Of the 12 items listed, three were rated by both supervisors and management as causing accidents relatively more frequently than other items. These items were just being careless and not following safety rules, just not giving a damn, and not using good common sense and judgement.

This appears to support DeJoy's (*8*) arguments concerning the existence of a biased tendency for supervisors to perceive workplace accidents as caused by factors internal to the worker (as opposed to themselves or to the worker's environment). He states:

> The supervisor is likely to explain the poor safety performance of people in his or her department in terms of employee carelessness or lack of effort. Attributing responsibility for poor safety performance to factors internal to the employees also tends to absolve the supervisor of direct blame.

In comparison with the low-accident mines, managers in high-accident mines felt that accidents were caused more often by miners worrying about debts, being upset about marriage problems, bad health and feeling bad, and hurrying to begin a vacation.

5. Safety and health equipment

As a group, underground miners felt that the two primary reasons for not using safety and health equipment were that it is uncomfortable, and that it gets in the way of working. Underground miners did not feel that other miners making fun of persons wearing equipment was a reason for equipment not being used. Significant differences were found in several instances between mean responses of personnel in low-accident mines and high-accident mines. Poor equipment maintenance, lack of training, and the fact that equipment isn't any good were cited as being important as reasons for not using equipment by underground miners in high-accident mines. On the other hand, the fact that there is no need for it and that it is difficult to get were cited as being more important as reasons for not using equipment by underground miners in low-accident mines.

6. Training

There is a consistent tendency for training on various topics to be rated as better by underground miners at low-accident mines. Results emphasize the importance of good training. Good training in how the electrical power system works, dealing with hazards (such as gases, coal dust, and noise), and how to use tools and equipment is more prevalent in mines with lower accident rates. Although safety training is reportedly offered to all employees, and a variety of training techniques are used, Pfeifer notes that "it apparently quite often misses the mark."

7. Safe job behaviors of miners and supervisors

Miners in low-accident mines reported that other miners wear safety glasses and cleanup the work area more often, and they bridge the circuit breaker when a circuit overloads less often than miners in high-accident mines.

In the underground miners group, significant differences were observed between mean responses in high-versus low-accident mines on 6 of the 12 items. Miners in low-accident mines reported that miners get along with each other, can depend on each other, and report small accidents more often than did miners in high-accident mines. On the other hand, workcrews apparently try to outdo other crews, and miners get mad if another miner works too fast or too slow more often in high-accident mines.

Miners in low-accident mines reported that they wear safety glasses, report safety and health hazards to the supervisor, and go to the doctor when they are sick significantly more often than miners in high-accident mines.

Surprisingly, miners in low-accident mines also reported that they take chances or cut corners and smoke in the mine significantly more often than miners in high-accident mines.

According to the responses of underground miners, the following behaviors of supervisors occur more often in low-accident mines:

1. Allowing miners to work at their own speed.

2. Giving miners a pat on the back when they follow safety procedures.

3. Wearing respirators in dusty conditions.

4. Reminding miners of safety and health practices.

5. Showing real concern for workers' welfare.

Miners' responses also suggest that supervisors in low-accident mines also refrain from the following activities:

1. Asking miners to do things that are against miners' better judgment.

2. Cutting corners on safety.

3. Pushing hard for production.

Miners in low-accident mines indicated that they had to do three activities significantly less frequently than miners in high-accident mines: doing a lot of things at the same time, working without clear-cut duties, and taking care of absentees' jobs. Supervisors in low-accident mines felt that miners had to take care of absentees' jobs significantly less often than in high-accident mines. In comparison with high-accident mines, significantly fewer managers in low-accident mines felt that miners had to answer to more than one person.

8. Company safety programs

Safety directors ranked the relative effectiveness of five types of safety incentives as follows:

- inclusion of safety attitude and behavior in worker performance evaluations.
- publicity of outstanding safety performance.
- running tally of accident-free employee-hours.
- recognition awards.
- cash awards and/or prizes (least effective).

Safety directors were asked what changes they would suggest to make their positions more effective. The most frequent response, given by eight safety directors, was that they should be given more authority in safety matters.

9. Perceptions of union influence on safety

Underground miners in low-accident mines reported that the union bargained with management for safer and healthier mines and discussed safety and health topics in union meetings to a significantly greater extent than underground miners in high-accident mines. Union officials in low-accident mines felt that the union took care of injured miners and their families to a significantly greater extent than union officials in high-accident mines.

CONCLUSIONS

Pfeifer concludes:

results of the survey seem to underline the fact that future improvements in accident records are dependent mainly on behavioral techniques. It appears that training is the behavioral technique considered most often by miners and management alike as a way of dealing with human error. However, other behavioral techniques as well appear promising on the basis of survey results. These techniques include OD techniques, work organization, programs to increase the frequency of safe job behaviors, improvements in company safety programs, redesign of safety equipment, and programs to reduce occupational stress.

Rhoton, W. A Procedure To Improve Compliance With Coal Mine Safety Regulations. J. of Organizational Behav. Manage., v. 2, No. 4, 1980, pp. 243-249.

OBJECTIVE

The purpose of this study was to determine the effects of an intervention on the rate of MSHA ventilation violation notices.

METHOD

Data were collected from crews of unionized, underground coal miners. Coal was produced in each of four sections, during two out of three shifts. Each section had one supervisor who was responsible for the production and safety performance of the crew. Every section had between six and nine production employees, as well as several maintenance and support crews working. There was a total of 195 union employees and 30 exempt employees.

The experimenter was a health and safety inspector from within the company's safety department. The outcome measure was the number of ventilation violation notices issued per month by MSHA inspectors. The experimenter's goal was to receive zero violation notices during the intervention phase. On a random basis, there was one inspection every week. During each inspection, five criti-cal performance variables were monitored: (a) making a methane gas check at the working face every 20 min; (b) maintaining a flow of at least 3,000 ft^3/min of intake air behind the line brattice; (c) maintaining proper calibration of equipment methane monitors; (d) keeping the line brattice to within 10 ft of the working face; and (e) keeping the area behind the line brattice free of accumulation of loose coal dust.

When the target behaviors were in compliance, the crew members and the supervisors were praised. Furthermore, graphic feedback of the ventilation violation notices were presented in the mine office. To supplement these graphs, verbal feedback was delivered biweekly by the experimenter during regular safety meetings with the supervisors. When a section was found to be noncompliant, the experimenter would stop production of coal until the hazardous condition was corrected.

RESULTS

During a 3-month baseline period, the mean number of ventilation citations issued per month was 2.6, based upon a mean of 13.3 inspection days per month. During the intervention phase, the mine operated for 10 consecutive months without a single ventilation citation. In the 14th month of the investigation, there was a brief return to baseline. At that time, a citation was issued during each of two consecutive MSHA inspections. These inspections coincided with the week in which the experimenter was absent due to illness. With the return of the experimenter to work, and consequent resumption of the systematic control mechanisms, the citations measure returned to zero.

CONCLUSION

The results of this study suggest that compliance with safety requirements can be increased with the use of frequent observation, contingent positive feedback, and praise. However, the relative contribution of each these components to producing the observed outcome is open to question.

Sanders, M., T. Patterson, and J. Peay. The Effect of Organizational Climate and Policy on Coal Mine Safety (contract HO242039, U.S. Dep. Navy). BuMines OFR 108-77, 1976, 180 pp.; NTIS PB 267 781.

OBJECTIVE

This study examined the causal influence of organizational climate and policy on underground coal mine safety.

METHOD

Data on total injuries and employment hours per mine were obtained from the Bureau. Mines in five States (Virginia, West Virginia, Kentucky, Pennsylvania, and Ohio) having at least 80 employees for 1972 and 1973 and working 1,600 employeehours per employee were selected to form a sampling pool. After percentile ranking of lost-time injury rates, mines in the top and bottom 30 pct of the industry for the two report years were proportionately selected within each state to insure a wide differential in accident rates. Percentile criteria were relaxed until a sufficient number of mines needed in each State had agreed to cooperate.

A total of approximately 250 miners from 22 mines completed questionnaires assessing 21 organizational climate, structure, and function dimensions on two occasions approximately 7 months apart. The responses for each item on the questionnaires were averaged across miners within each mine. The item means were then combined to yield climate scale scores for each mine. The 21 dimensions were as follows: achievement motivation, autonomy, consistency of orders, cooperation among workgroups, decision decentralization, continued employee development, identification with company, innovative flexibility, feedback, management receptiveness, morale, new worker development, performance reward dependency, management planning, production pressure, shared authority, social relations among workers, structure, support for workers, decision timeliness, and concern for working conditions.

The association of the questionnaire data to the rates of lost-time injuries during 1972-1973 was assessed using a cross-lagged panel design.

RESULTS

The results strongly suggest that:

1. When decisions are decentralized, when management is flexible and innovative in trying new procedures and programs, and when morale is high, disabling injuries decrease.

2. As disabling injuries increase, feedback, continued employee development, and consistency of order improve, which then appear to decrease injuries.

3. Production pressure appears to lead to an increase in disabling injuries, which in turn results in a decrease in production pressure.

4. Mines in which management plans effectively tend to have a lower incidence of injury than other mines.

5. Mines in which miners are given decision responsibility and autonomy tend to have a lower incidence of injuries than other mines.

CONCLUSIONS

Sanders concludes that, because his analyses are based on a cross-lagged panel design, there is clear evidence that organizational climate and management practices do affect the injury experience in underground coal mines, and are not simply the consequence of changes in the injury experience. Sanders also proposes that training mine management in basic supervisory employee relations and planning skills would significantly impact on the injury rates of the mines.

Uslan, S., H. Adelman, and R. Keller. Testing the Effects of Applied Behavioral Analysis and Applied Behavioral Management Techniques on the Safe Behaviors of Salt Mine Personnel (contract JO166137), Salt Inst.). BuMines OFR 44-80, 1978, 44 pp.; NTIS PB 80-171309.

OBJECTIVE

The purpose of the study was to demonstrate the effect of a training intervention (to teach use of positive social reinforcement) on the frequency of eye, hand, and back injuries at four salt mines.

METHOD

The intervention was called positive motivational safety training (POMOST). This training provides supervisors with:

> ... an understanding about behavior and a process by which they can improve performance; increase safe work behaviors, help the employee feel better about himself, the company, and his job; and generally establish a work environment which is positively supportive.

The principal reinforcer used in POMOST is praise, i.e., positive verbal feedback. POMOST instructs trainees in when and how to praise their employees. The program was taught in 22 to 40 h, depending on need. The program objectives were as follows:

How to recognize unsafe behaviors.

How to develop behavior baselines.

How to determine what behaviors to change.

How to communicate behavior change to employees.

How to shape behaviors.

How to maintain a safe work behavior program.

This training discourages the use of punishment. Rather, emphasis is placed on the first line supervisor focusing the employees' attention on the appropriateness of their behavior. The existence of inappropriate behavior is not ignored, but perceived as a training problem.

Approximately 100 managers and supervisors from four plants were trained in the use of positive reinforcement for occurrences of safe behavior. Each supervisor was also provided manuals and other supportive materials. Additionally, following training, all supervisors were provided some coaching experience to keep the knowledge and capabilities gained during training from being extinguished.

Because of the high frequency of eye, head, hand, and back injuries, supervisors were asked to concentrate on shaping the following behaviors:

SIMPLE BEHAVIORS–wear safety devices, lift correctly, drive safely, use tools properly, and maintain housekeeping standards.

MORE COMPLEX BEHAVIORS–suggest better work methods, identify unsafe conditions, self-enforce safety practices, assist fellow workers who need help lifting, driving, loading, etc.

A pre-training baseline was determined for each plant that identified rates of various types of accidents and injuries. The design was a before and after time series design. All the months prior to the onset of training represent the total number of premeasures; those subsequent to training represent all the measures of the post period. A 2 by 2 chi square contingency table was constructed which compared the pre and post periods for the number of months in which the totals were above and below the means.

In addition, a pre-training mean was computed separately for each site. Each post training total was then compared to determine the number of monthly totals which were above or below the pre-training mean.

RESULTS

Injury data were adjusted for total manhours at three of the four sites. The rates at two of these three sites show statistically significant decreases in injury rate frequencies, while the other site shows no change. In terms of frequencies unadjusted for hours of exposure, three experimental sites showed a decrease in injury frequency from pre to post training periods while the fourth showed an increase.

The mean injuries of each of the four sites for the pre versus post periods were combined and an average of those means was computed. The average for the pre-intervention period was 10.83 injuries per month and the post intervention average was 9.28 injuries per month.

Wagner, J. Time-Of-Day Variations in the Severity of Injuries Suffered By Mine Shiftworkers. Paper in Proceedings of the 32nd Annual Meeting of the Human Factors Society. Anaheim, CA, 1988, 11 pp.; available upon request from J. Wagner, BuMines, Minneapolis, MN.

OBJECTIVE

This study examines the hypotheses that (1) the average severity of accidents experienced by operators of heavy mining equipment would be greater than for other types of mine employees, and (2) that this difference would be especially pronounced on the night shift.

METHOD

Based on the studies of industrial shiftworkers in France, Andlauer (*2*) suggests that accidents on the night shift are less frequent, but of greater severity than day shift accidents. It is argued that there may be an etiological relationship between accidents and greater nervous activity: at times of hyperactivity (or excitability) accidents are more frequent and less serious, while at times of hpyoactivity (or inhibition) accidents are less frequent, but more serious. Therefore, it is hypothesized:

> A worker performing automatically, especially during periods of low alertness and arousal, will tend to introduce few errors into his or her routine tasks, thereby limiting the likelihood of suffering an accident. However, the inhibited state of psychological arousal coupled with a narrow conscious focus on the routine task at hand does not allow the employee to respond properly to emergencies, thereby promoting the causation of relatively severe accidents.

Wagner examined this hypothesis by comparing the average severity of accidents that involved the operation of heavy mining equipment versus accidents involving miners performing other types of activities–ones that presumably require less vigilance to perform the job safely.

Accidents from 10 taconite[3] operations over a 10 yr period were considered. These surface mines and associated ore processing plants are all located in northern Minnesota and Michigan. All of the 10 mining operations were similar in terms of equipment, mining and hauling techniques, work force requirement, and management approach. Most importantly, all worked an identical shift rotation for the full 10-yr period, a rotation which required weekly shift rotation with a run of night duty (7 nights) which always started on a Thursday night after 56 h of free time.

Accidents were broken down according to the shift (day, afternoon, night) and according to whether the accident occurred during equipment operation (selected accidents) or during the course of performing some other type of activity (nonselected accidents). The average number of days lost per accident was used as the measure of accident severity.

RESULTS

The day shift accounted for 4,103 accidents, compared with 1,572 for afternoon, and 814 for night shift. Data are unavailable for normalizing these number, i.e., it was impossible to compute rates of accidents per employee hours of exposure.

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[3]Taconite is a low-grade iron ore.

It was found that among selected accidents, the night shift accidents are more severe (24.38 days lost) than the accidents experienced on the day shift (19.96 days lost) or the afternoon shift (17.84 days lost). Among nonselected accidents, night shift accidents are also more severe, but by a much smaller margin compared with the other two shifts. These data appear to confirm findings by Andlauer (*2*) and others regarding automatic behavior and employees' inability to respond adequately in emergency situations during times such as the night shift when vigilance is difficult to maintain.

In contrast to Wagner's finding that mobile equipment operators experience more severe accidents than other mine employees, Bennett (*4*) found that mobile equipment operators in the underground coal mining industry had the same probability of suffering a serious (lost time) injury as all other job classifications. There are several potential explanations for this discrepancy in findings. Wagner was looking at data from miners in the iron ore mining industry who were all working the same rotating shift schedule, whereas Bennett was comparing miners throughout the underground coal industry who were using different types of mobile equipment and who were working on a wide variety of different types of work schedules. Also, the two studies used different approaches to operationally define accident severity.

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